ISSN: 2977-4047

Journal of Life Sciences Research and Reviews

SCIENTIFIC Research and Community

Research Article

Open Access

Response of Malt Barley to NPSZnB and Urea Fertilizers Across Soil Types and Agro-ecologies, Arsi Zone of Oromia, South-Eastern Ethiopia

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ABSTRACT

Field trials were conducted on farmers' fields during the 2017, 2018, and 2019 cropping seasons to determine the optimum NPSZnB and urea fertilizer rates for selected crop, soil, and climatic conditions, as well as to assess the economic feasibility of blended and urea fertilizer rates for malt barley by varying levels of NPSZnB fertilizer (0, 100, 150, 200, 250 kg ha^{-1}) and recommended NP in combined RCBD with three replications on growth performance and yield. The post-harvest soil analysis results of experimental sites revealed that the use of treatments significantly ($p< 0.05$ and $p< 0.001$) altered pH, total N, available P, and organic matter for samples taken from malt barley crop experimental sites. Application of different fertilizer levels significantly affected post-harvest pH and organic carbon contents. A significant improvement was observed in soil chemical contents compared to the contents of the soil before treatment application at Lemu-Bilbilo district. Combined levels of NPSZnB and urea fertilizer rates significantly affected grain and above-ground biomass yields at Lemu-Bilbilo and Kofele districts. The maximum grain and biomass yield (6197 and 11018 kg ha^{-1}) in 2019 and minimum (3646 and 6875 kg ha^{-1}) in the 2018 cropping season were obtained, respectively at Lemu-Bilbilo district up on the application of NPSZnB and urea fertilizers. Similarly, significant grain and biomass yield (5554 and 10412 kg ha^{-1}) were obtained from the application of 250 + 200 and 250 + 150 kg ha^{-1} NPSZnB with urea fertilizer, respectively. The maximum grain and biomass yield (5244 and 10092 kg ha^{-1}) in 2019 and minimum (3477 and 7736 kg ha^{-1}) in 2017 and 2018 cropping season were obtained, respectively at Kofele district from the application of NPSZnB and urea fertilizers. Similarly, a significant grain and biomass yield (5125 and 9826 kg ha^{-1}) were obtained from the application of 250 + 150 and 250 + 200 kg ha^{-1} NPSZnB + urea, respectively.

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Received: June 24, 2024; **Accepted:** July 08, 2024; **Published:** July 31, 2024

Keywords: Experiment, NPSZnB and Urea fertilizers, Malt barley

Introduction

Barley is a cool-season crop that is adapted to high altitudes. It is grown in a wide range of agro climatic regions under several production systems. At altitudes of about 3000 m or above, it may be the only crop grown that provides food, beverages, and other necessities to many millions of people. Barley grows best on well-drained soils and can tolerate higher levels of soil salinity than most other crops. Food barley is commonly cultivated in stressed areas where soil erosion, occasional drought, or frost limits the ability to grow other crops [1]. Malting barley, however, requires a favorable environment to produce a plump and mealy grain. The diversity of barley ecologies is high, with a large number of folk varieties and traditional practices existing in Ethiopia, which enables the crop to be more adaptable in the highland areas [2].

The area devoted to barley production in Ethiopia over the past 25 years has fluctuated. It was around 0.8 million hectares in the late 1970s and rose to more than 1 million hectares in the late 1980s. It then declined and remained between 0.8 and 0.9 million hectares until the beginning of the third millennium. The production of barley, by-and-large, has been below 1 million ton per year for most of the past 25 years, except during the years when the area under barley increased above 1 million hectares. Despite of the importance of barley as a food and malting crop, and the efforts made so far to generate improved production technologies, its productivity in production fields has remained very low (about 1.3 t ha^{-1} compared with the world average of 2.4 t ha^{-1}) [3]. This is primarily due to the low yielding ability of farmers' cultivars, which are the dominant varieties in use; the influence of several biotic and abiotic stresses; and the minimal promotion of improved barley production technologies. The most important abiotic stresses include low soil fertility, low soil pH, poor soil drainage, frost and drought [4].

Fertilizer use trend has been focused mainly on the use and application of nitrogen and phosphorous fertilizers in the form of Di-ammonium phosphate and Urea as blanket recommendation for the major food crops in Ethiopia. Continuous application of nitrogen and phosphorus fertilizers without due consideration of other nutrients led to the depletion of other important nutrient elements such as potassium, magnesium, calcium, sulfur and micronutrients in soils. Balanced fertilization is the key to sustainable crop production and maintenance of soil health. It has both economic and environmental consideration. An imbalanced fertilizer use results in low fertilizer use efficiency leading to less economic returns and a greater threat to the environment [5]. The soil fertility mapping project in Ethiopia reported that deficiency

of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils were common [6].

Therefore, this experiment was designed to investigate the response of malt barley to NPSZnB and urea fertilizers with the specific objective to determine optimum NPSZnB and urea fertilizer rates for malt barley crop, soil and climatic conditions; to assess economic feasibility NPSZnB and urea fertilizer rates for barley crop; to develop guideline for blended fertilizer based on soil test and crop response to fertilizers on representative soils; to quantify their comparative advantage over the traditional fertilizer recommendation.

Materials and Methods

Descriptions of the study Area

The experiment was carried out on farmers' fields and on research stations for three cropping seasons during 2017-2019 at Lemu-Bilbilo and Kofele districts in Arsi zone of Oromia, South-eastern Ethiopia. Geographically, the study area is located between 070 36' 870" to 070 27' 530" N, and 0390 14' 270" to 0390 15' 133" E with an elevation ranging from 2526-2873 meters above sea level at Lemu-Bilbilo, and 070 56' 648"N latitude, 380 47' 584"E longitude at altitude of 2662 meters above sea level at Kofele district. The average weather data recorded on the weather station of the study areas from the years 2017 - 2019 indicate that 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 ^{0}C) and (18.5, 20.3, 20.5 ^{0}C), respectively.

Design and Treatments

The experiment was set in combined RCBD by varying levels of NPSZnB fertilizer (0, 100, 150, 200, 250 kg ha^{-1}), and Urea (0, 100, 150, 200 kg ha^{-1}) with three replications. The size of each experimental gross plot was 2.6 m x 4 m (10.4 m^2). The malt barley variety used for the experiment at both locations was Ibon. 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.

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 Lemu-Bilbilo and Kofele districts indicated that the pH value were 5.64 (moderate) and 5.78 (moderate), available phosphorus were 11.35 ppm (high) and 7.57 ppm (medium), total N were 0.26 % (high) and 0.24 % (medium), and Organic matter 5.55 % (high) and 4.36 % (medium), respectively [7-9] (Table 1).

Yield data collection

Data of, grain yield, biomass, and thousand seed grain weight and hectoliter weight were collected from each plot. Grain and biomass yield and were analyzed gravimetrically by using sensitive balance and recorded in units of gram.

Statistical analysis

The ANOVA procedure of statistical analysis system was used for performing the significance of differences in grain and biomass yield parameters [10]. A post hoc separation of means was done by least significant difference (LSD) test after main effects was found significant at $P < 0.05$.

Results and Discussions

Soil Chemical Properties of the Study Area before and after planting

Table 1: Some chemical properties of soil of the experimental sites before planting before planting at Lemu-Bilbilo and Kofele districts.

Location	pH (1:2.5)	Av.P (ppm)	Total N (%)	OC (%)	OM (%)
Lemu-Bilbilo	5.64	11.35	0.26	3.22	5.55
Kofele	5.78	7.57	0.24	2.53	4.36

The results of the soil chemical properties of Lemu-Bilbilo district. are indicated in Table 2. The soil analysis results of experimental sites at post-harvest showed that the application of treatments significantly ($p < 0.05$ and $p < 0.001$) affected pH, total N, available P, and organic matter for samples taken from experimental sites of the malt barley crop. Application of different fertilizer levels had significant effects on post-harvest pH and organic carbon contents. A significant improvement was observed in soil chemical contents compared to the contents of the soil before treatment application at Lemu-Bilbilo district (Table 2).

Table 2: Soil chemical properties after harvesting at Lemu-Bilbilo district.

Treatments						
NPSZnB (kg ha^{-1})	**Urea (kg ha^{-1})**	**pH (1:2.5)**	**AvP (ppm)**	**Total N (%)**	**OC (%)**	**OM (%)**
0	0	5.69	22.69	0.28	2.94	5.07
100	100	5.66	22.45	0.24	3.76	6.48
100	150	5.73	21.31	0.28	3.00	5.16
100	200	5.84	20.43	0.29	3.29	5.67
150	100	5.74	21.00	0.24	3.38	5.82
150	150	5.57	23.04	0.26	3.67	6.34
150	200	5.54	24.31	0.23	3.39	5.84
200	100	5.56	24.80	0.30	3.68	6.35
200	150	5.81	21.97	0.30	3.88	6.69
200	200	5.60	24.61	0.26	3.85	6.63
250	100	5.62	21.70	0.27	3.65	6.29
250	150	5.62	21.32	0.26	3.53	6.09
250	200	5.68	24.50	0.28	3.49	6.02
Mean		5.67	22.62	0.27	3.50	6.04
F-prob.		***	*	*	***	***
LSD 0.05		0.11	2.62	0.04	0.18	0.32
CV (%)		1.12	6.91	8.68	3.13	3.11

*, *** = significant at $p < 0.05$, and $p < 0.001$

Effect of NPSZnB and urea fertilizers on yield and yield components of malt barley

The maximum grain and biomass yield (6197 and 11018 kg ha^{-1}) in 2019 and minimum (3646 and 6875 kg ha^{-1}) in 2018 cropping season were obtained, respectively at Lemu-Bilbilo district from the application of NPSZnB and urea fertilizers. Likewise, significant grain and biomass yield (5554 and 10412 kg ha^{-1}) were obtained from the application of 250 + 200 and 250 + 150 kg ha^{-1} NPSZnB + urea, respectively (Table 3).

Table 3: Effect of NPSZnB and urea fertilizers on Grain) and biomass yield of malt barley at Lemu-Bilbilo and Kofele districts.

		Lemu-Bilbilo	**Kofele**		
Factors		**GY (kg ha^{-1})**	**BY(kg ha^{-1})**	**GY (kg ha^{-1})**	**BY (kg ha^{-1})**
Year					
2017		5253b	8568b	3477c	8410b
2018		3646c	6875c	4389b	7736c
2019		6197a	11018a	5244a	10092a
LSD (≤0.05)		208.0	607.2	244.0	505.8
		Fertilizers rate, kg ha^{-1}			
NPSZnB	**Urea**				
0	0	3241f	5329e	3093f	7010d
100	100	4479e	7782d	3878e	8345bc
100	150	4998d	8534cd	4557bcd	9355ab
100	200	5107bcd	8691bcd	4265de	8668bc
150	100	4967d	8749bcd	3898e	7899cd
150	150	5077cd	8863bcd	4304de	8794abc
150	200	5356abcd	9360abc	4448cd	8948abc
200	100	4998d	8822bcd	4881abc	8809abc
200	150	5293abcd	9442abc	4724abcd	8394bc
200	200	5487abc	9842ab	4326de	8587bc
250	100	5344abcd	9104bc	4362de	9291ab

250	150	5512ab	10412a	5125a	9779a
250	200	5554a	9730abc	5047ab	9826a
CV(%)		13.1	21.8	12.4	12.9
LSD0.05		433.0	1264.1	507.8	1052.9

A maximum grain and above ground biomass yield (5244 and 10092 kg ha-1) in 2019 and minimum (3477 and 7736 kg ha^{-1}) in 2017 and 2018 cropping season were obtained, respectively at Kofele district up on the application of NPSZnB and urea fertilizers. Similarly, significant grain and biomass yield (5125 and 9826 kg ha^{-1}) were obtained from the application of 250 + 150 and 250 + 200 kg ha^{-1} NPSZnB + urea, respectively (Table 3).

The maximum value of harvest index (52.8 %) in 2018, HLW (67.7 ghL^{-1}) in 2017, thousand seed weight (52.8 g) in 2019, and minimum (50.6 %) in 2017,(62.7 ghL^{-1}) in 2019, (44.5 g) in 2018 cropping season were obtained, respectively at Lemu-Bilbilo district up with the application of NPSZnB and urea fertilizers. Similarly, significant value of harvest index (53.9 %) with the application of (100, 200), HLW (65.5 ghL^{-1}) with the application of (100, 150) and (100, 200), thousand seed weight (49.9 g) with the application of (200, 150) kg ha^{-1} NPSZnB and urea were obtained, respectively (Table 4).

Table 4: Effect of NPSZnB and urea fertilizers on Harvest index hectoliter weight and thousand seed weight on malt barley at Lemu-Bilbilo and Kofele districts.

Factors		**Lemu-Bilbilo**			**Kofele**		
		HI (%)	**HLW (gm hL^{-1})**	**TKW (gm)**	**HI (%)**	**HLW (gm hL^{-1})**	**TKW (gm)**
Year							
2017		50.6b	67.7a	48.6b	42.1c	65.6a	46.2a
2018		52.8a	64.7b	44.5c	55a	56.8b	40.7b
2019		51.5ab	62.7c	52.8a	49.2b	57.3b	46.2a
LSD0.05		1.6	0.6	0.6	1.7	1.0	0.8
	Fertilizers rate, kg ha^{-1}						
NPSZnB	**Urea**						
0	0	53.4ab	64.2b	46.6d	45.3e	58.6ab	41.9c
100	100	51.1ab	64.5ab	47.4cd	46de	60.2ab	44ab
100	150	52.4ab	65.5a	48.3bc	49.2abcd	60ab	44ab
100	200	53.9a	65.5a	48.4bc	49.8abc	60ab	43.9ab
150	100	51.7ab	65.3ab	48.1bc	48.7abcde	60ab	43.7b
150	150	50.9ab	65.1ab	49ab	46.3cde	60.2ab	44.7ab
150	200	51.4ab	65.4ab	48.3bc	48.2bcde	59.8ab	43.9ab
200	100	50.4b	64.8ab	49.2ab	51.7ab	58.6b	45.2ab
200	150	50.7ab	65.3ab	49.9a	51.7ab	60.1ab	45.4a
200	200	50.5b	64.9ab	49ab	47.7cde	60.7a	45.2ab
250	100	53ab	65.2ab	49.1ab	47.8cde	59.9ab	44.5ab
250	150	51ab	64.9ab	49ab	52.3a	60ab	45.2ab
250	200	50.4b	65.1ab	49.4ab	49.3abcd	60.5ab	45.3a
CV(%)		10.0	3.0	4.2	7.9	3.7	3.8
LSD0.05		3.4	1.3	1.3	3.6	2.1	1.6

The highest value of harvest index (55.0 %) in 2018, HLW (67.6 ghL^{-1}) in 2017, thousand seed weight (46.2 g) in 2017 and 2019, and lowest (42.1 %) in 2017,(56.8 ghL^{-1}, 40.7 g) in 2018 cropping season were obtained, respectively at Kofele district with the application of NPSZnB and urea fertilizers. Similarly, significant result of harvest index (52.3 %) with the application of (250, 150), HLW (60.7 ghL^{-1}) with the application of (200, 200) and thousand seed weight (45.4 g) with the application of (200, 150) kg ha^{-1} NPSZnB and urea were obtained, respectively (Table 4).

Table 5: Effect of NPSZnB and urea fertilizers on yield and yield components of malt barley at Lemu-Bilbilo district (2019 cropping season).

NPSZnB	Fertilizer rate, kg ha^{-1}		Lemu-Bilbilo		Kofele		
	Urea	GY (kg ha^{-1})	BY (kg ha^{-1})	HI (%)	GY (kg ha^{-1})	BY (kg ha^{-1})	HI (%)
0	0	4697c	7705c	54.4a	3221e	6739f	48.5ab
100	100	5551bc	9484bc	52.9ab	4463d	9679de	45c
100	150	6563a	11487ab	51.4abc	6012ab	11367ab	50.4ab
100	200	6475ab	11161ab	52.8ab	4547d	8751e	51.3a
150	100	6400ab	11213ab	53.7ab	4243d	8663e	49.1ab
150	150	6154ab	11214ab	48.7cd	5442c	9759cde	49.9ab
150	200	6190ab	11172ab	50.5bcd	5740abc	10825abcd	48.4ab
200	100	6115ab	10687ab	50.6bcd	5918abc	10394bcd	50.6ab
200	150	6364ab	12018ab	51abc	6203a	10531bcd	51.1a
200	200	6385ab	11538ab	51.7abc	5502bc	11214abc	47.5bc
250	100	6103ab	10601ab	53.7ab	5805abc	11417ab	49ab
250	150	6847a	13009a	47.2d	5863abc	12125a	47.7bc
250	200	6719a	11944ab	50.4bcd	5510bc	9740de	50.7ab
RNP		5983ab	10135bc	54.2a	5523bc	10363bcd	50.6ab
Mean		6182	10955	51.7	5285	10112	49.3
CV(%)		13.4	21.2	5.8	6.4	8.6	4.0
LSD0.05		956.6	2668.7	3.4	566.3	1456.0	3.3

RNP = Recommended Nitrogen and Phosphorus

Malt barley analysis result revealed that, as indicated in table 5, the maximum grain and above ground biomass yield (6847 and 13009 kg ha^{-1}) were obtained from the application of 250 and 150 kg ha^{-1} NPSZnB and urea fertilizers rate; and minimum at the control (4697 and 7705 kg ha^{-1}), respectively. Thus, the blanket recommendation has got grain (2.0 to 12.6%) yield lose over the other remaining treatments at Lemu-Bilbilo district. Similarly, the highest (6203 and 12125 kg ha^{-1}) grain and above ground biomass yield were obtained from the application of (200, 150) and (200, 200) kg ha^{-1} NPSZnB and urea fertilizers rate and lowest at the control, respectively. Thus, the blanket recommendation has got grain (3.8 to 11.0%) yield lose over the other remaining treatments at Kofele district (Table 5).

Conclusions and Recommendations

The results of soil analysis at the experimental location showed that the application of the treatment given could improve pH, total N, available P, and soil organic matter.

This research found that the application of NPSZnB and urea fertilizers in Lemu Bilbilo District was able to increase grain and biomass yields from 3646 kg/ha and 6875 kg/ha respectively in 2018 to 6197 kg/ha and 11018 kg/ha respectively, in 2019. The best dose of NPSZnB and urea fertilizer in increasing grain yield and biomass is 250 kg/ha NPSZnB + 150 kg/ha urea.

In the Kofele district, the application of NPSZnB and urea fertilizers can also increase grain and biomass yields in 2019, respectively by 5244 kg/ha and 10092 kg/ha, compared to previously in 2018 respectively 3477 kg/ha and 7736 kg/ha. Ha. The best doses of NPSZnB and urea fertilizer that can increase grain yield and biomass are respectively 200 kg/ha NPSZnB + 150 kg/ha urea, and 250 kg/ha NPSZnB + 150 kg/ha urea.

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