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(Research Article)

Response of barley to different rates of NPS and NPSB Fertilizers in the highland of Bule Woreda, Southern Ethiopia

Mulugeta Habte *, Abay Ayalew and Atinafu Assefa

Southern Agricultural Research Institute, Hawassa Agricultural Research Center, Department of Natural Resource Management, Hawassa, Ethiopia.

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Abstract

One of the main constraints for sustainable barley production is lack of information on the use of multi-nutrient fertilizers, involving the actual limiting nutrients for specific site. On farm experiment was conducted in 2016 and 2017 cropping seasons on two farmers' field to evaluate the effect of NPS and NPSB, and to determine their optimum rates for barley production in Bulle woreda. The experiment consisted of nine treatments, including control (no fertilizer)(T1); four rates of NPS at 46 kg N. 23.5 kg P, 10 kg S/ha (T2), 69 kg N, 31 kg P, 13 kg S/ha(T3), 92 kg N, 39 kg P, 17 kg S/ha (T4), 92 kg N, 23.5 kg P, 10 kg S/ha (T5); and four rates of NPSB at 46 kg N, 23.5 kg P, 10 kg S, 1.07 kg B/ha(T6), 69 kg N, 31 kg P, 13 kg S, 1.4 kg B /ha (T7), 92 kg N, 39 kg P, 17 kg S, 1.7 kg B/ha(T8) 92 kg N, 23.5 kg P, 10 kg S, 1.07 kg B/ha (T9) were laid out in a randomized complete block design with three replications. Except the absolute control, all plots received 50 kg K/ha. Results of ANOVA indicated that application of NPS and NPBS significantly ($P < 0.05$) improved plant height, biomass and grain yield compared to control. NPS application at 92 kg N, 23.5 kg P and 10 kg S + 50 kg K/ha followed by NPSB at 69 kg N, 31 kg P, 13 kg S and 1.4 kg B + 50 kgK/ha recorded highest barley grain yield and resulted in 5271 and 5158 kg/ha, respectively, while the lowest yield was recorded for the unfertilized plot. In general, effects of NPS or NPSB were not significantly different, suggesting that farmers' could invest in NPS for increased barley production. This treatment also gave higher net benefit with acceptable marginal rate of return even under projected (20%) input price increment.t Therefore, we could recommend the application of 92 kg N, 23.5 kg P and 10 kg S + 50 kg K/ha (142 kg NPS + 142 kg urea + 100 kg KCl kg/ha) for barley production in the study area. The response of barley to NPSB (inclusion of B in NPS) and NPS effect on barley with respect to RNP still needs to be widely investigated.

Keywords: Biomass yield; grain yield; Soil nutrient; Economic benefit

1 Introduction

Barley (Hordeum vulgare L.) is one of the main cereal crops produced in the Ethiopian highlands. It grows in the range of 1500–3500 masl, but is predominantly grown between altitudes of 2000 and 3000 masl (Hailu and van Leur, 1996). In Ethiopia, based on area of production, barley is ranked fifth of all cereals, but third in yield per unit area (CSA, 2004). Although barley is the most important cereal crop, the national average yield has remained low at below 2.1 t/ha (CSA, 2017), whereas the potential yield goes up to 6 t/ha on experimental plots (Berhane et al., 1996). Soil fertility is the most limiting factor for barley production in the highlands of Ethiopia (Woldeyesus and Chilot, 2002). Due to the undulating nature of the land in these areas, the soil is washed out every year. Continuous cropping, high proportion of cereals in the cropping system, and application of suboptimal levels of mineral fertilizers aggravate the decline in soil fertility (Tanner et al., 1991; Workneh and Mwangi, 1992).

* Corresponding author: Mulugeta Habte; Email:mulugeta4habte@gmail.com

Farmers in the country, in general, and in the region (SNNPRS), in particular, use inorganic and organic inputs to counteract the production and productivity problems. However, despite significant rise in total fertilizer import from 250,000 tons in 1995 to 500,000 tons in 2012 (CSA, 2012), the intensity of fertilizer use has increased only marginally over the past decade from 31 kg/ha in 1995 to 36 kg/ha in 2008, which was still less than the blanket recommendation (Fufa and Hassen 2005; Alem et al., 2008); whereas fertilizer factor productivity declined by 63% during the same period.

Nutrient mining due to continuous cropping and sub optimal fertilizer use, in one hand, and unbalanced fertilizer (only N and P) uses on the other hand, have favored the occurrence of multi nutrient deficiency in Ethiopian soils (Abyie et al., 2003); which might have in part contributed to the decline in fertilizer factor productivity experienced over recent past. The national soil inventory data also revealed that, in addition to nitrogen and phosphorus, sulphur, boron and zinc deficiencies are widespread in Ethiopian soils, while some soils are also deficient in potassium, copper, manganese and iron (Ethiosis, 2013), which all potentially hold back crop productivity, despite continued use of N and P fertilizers as per the blanket recommendation. Hence, future gains in food grain production will be more difficult and expensive unless the increasing problem of multi nutrient deficiency is tackled.

New fertilizer materials with value addition/fortification with secondary and micronutrients would be required to ensure balanced fertilizer use and solve the problem. In line with this, it has been observed that supplementation of NP fertilizers by S, Zn, B, and K increased N fertilizer efficiency and maize yields by 40% over the standard N-P recommendation alone (John et al., 2000). The work of Wassie and Shiferaw (2011) in southern Ethiopia has also shown how fertilizer use efficiency of potato can be raised when NP fertilizers are combined with K on a location-specific basis, where supplementation of K increased potato tuber yields by 197% over the standard N-P recommendation alone.

Blanket applications of 100 kg DAP and 100 kg Urea have been used almost all over the country irrespective of the climate, soil type, crop species and variety.Therefore, it is high time to investigate nutrient dynamics in major production systems and establish site, crop and soil specific balanced fertilizer recommendations. Nitrogen, phosphorus, sulfur, and boron have been identified as deficient nutrients of the area in the soil fertility map of the region produced by Agricultural Transformation Agency (MOANR and ATA, 2016). However, fertilizer trials involving multi-nutrient blends that include micronutrients are rare in the country. Therefore, this study was initiated to provide site and crop specific balanced fertilizer recommendations for improved barley production in Bule area, southern Ethiopia.

2 Materials and Methods

A trial was conducted on two farmers' field to evaluate NPS and NPSB fertilizers and to determine optimum rates for improved barley production in Bule woreda of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in the main cropping seasons of 2016 and 2017. The experiment consisted of nine treatments with different rates of NPS and NPSB: control (no fertilizer)(T1); four rates of NPS at 46 kg N, 23.5 kg P, 10 kg S/ha (T2), 69 kg N, 31 kg P, 13 kg S/ha (T3), 92 kg N, 39 kg P, 17 kg S/ha (T4), 92 kg N, 23.5 kg P, 10 kg S/ha (T5); and four rates of NPSB at 46 kg N, 23.5 kg P, 10 kg S, 1.07 kg B/ha(T6), 69 kg N, 31 kg P, 13 kg S, 1.4 kg B /ha (T7), 92 kg N, 39 kg P, 17 kg S, 1.7 kg B/ha(T8) 92 kg N, 23.5 kg P, 10 kg S, 1.07 kg B/ha (T9). In addition, all plots received 50 kg K/ha as KCl, except the absolute control. The recommended N rate was adjusted by using urea.

2.1. Experimental layout

The experiment was laid out in a randomized complete block design replicated three times with a plot size of 4 m by 4 m (16m2). The spacings between plots and blocks were 1 m and 1.50 m, respectively. Whole doses of NPS, NPSB and KCl were applied at planting and urea adjustement was made by top dressing 45 days after planting. Improved barley variety HB- 1307 was planted in rows of 20 cm after application of fertilizers and thinly covered with soil at the seed rate of 100 kg /ha and all other field management practices were uniformly applied to all plots as recommended for the crop.

2.2. Data collection

Agronomic parameters such as plant height, number of tillers per plant, spike length, total above ground fresh biomass weight and grain yield were collected. Plant height, numbers of tillers per plant and spike length data were taken from randomly selected five plants.

2.3. Agronomic and economic data analysis

Collected data were subjected to Analysis of variance (ANOVA) using Proc GLM procedures of SAS version 5 (SAS Institute Inc., 2002). Least significant difference (LSD) was computed to separate treatment means at 5% probability level whenever significant difference between means occured. Economic analysis was also carried out to evaluate the feasibility of fertilizer rates for barley production. For partial budget analysis average yields were down adjusted by 10% by assuming that farmers would get about 10% less yield than is achieved on an experimental site. The average farm get price used for barley was 10.5 ETB/kg and the official prices for NPS, NPSB and Urea were 10.94, 10.28 and 8.76 ETB/kg), respectively. For a treatment to be considered a worthwhile, the minimum acceptable marginal rate of return should be over 50% (CIMMYT, 1988). However, Gorfu et al. (1991) have suggested that a minimum acceptable rate of return should be 100% and thus, used in this study.

3 Results and discussion

Application of NPS and NPSB, and their rates significantly ($P \leq 0.05$) influenced the plant height, total above ground biomass and grain yields of barley (Table 1). Tillers density and spike length were not affected by applied fertilizers and their rates. Similar rates of the two fertilizers were statistically at par suggesting that inclusion of B had no effect on barley production at Bule. However, there were significant differences among rates of NPS on plant height, biomass and grain yields, while signinficant differences among NPSB rates were observed only on biomass yield.

Combined analysis over years for the two sites indicated that significantly ($P \leq 0.05$) higher grain yield was recorded from plots treated with NPS at 92 kg N, 23.5 kg P and 10 kg S /ha (T 5) and NPSB at 69 kg N, 31 kg P, 13kg S and 1.4 kg B/ha (T 7) as compared to

Table 1 Yield and yield components of barley as influenced by different blended fertilizers rates in Bule woreda

	Treatments	Plantheight (cm)	No of tillers/plant	Spike length (cm)	Above ground biomass yield (t/ha)	Grain yield (kg/ha)
1.	No fertilizer	97.5c	8.0	6.3	8.68d	3409.0c
2.	NPS: 46,23.5,10 kg/ha	106.7b	8.3	6.6	10.89c	4332.4b
3.	NPS: 69, 31, 13 kg/ha	111.4ab	9.1	6.8	13.08a	4839.0 ab
4.	NPS: 92, 39, 17 kg/ha	112.4a	9.4	6.7	12.73ab	4815.6 ab
5.	NPS: 92, 23.5, 10 kg/ha	112.0ab	9.5	7.2	13.56 a	5271.9a
6.	NPSB: 46,23.5,10, 1.07 kg/ha	108.6ab	9.6	6.6	11.42bc	4605.9 ab
7.	NPSB: 69,31,13, 1.4 kg/ha	112.4a	10.0	7.1	13.21 a	5158.0 a
8.	NPSB: 92,39,17, 1.7 kg/ha	112.8a	9.4	6.9	12.88a	4812.1 ab
9.	NPSB: 92, 23.5, 10,1.07 kg/ha	112.1ab	9.7	6.9	12.52ab	4870.4 ab
	LSD at 0.05	5.51	NS	NS	1.3324	737.69
	V (%)	4.04	14.75	7.11	15.69	17.16

NPS at 45kg N, 23.5 kg P and 10 kg S/ha (T 2) and the control (T1), while the lowest yield was measured for the control plot. Although research on blended fertilizers is limited for all crops, Dejene and Fetien (2014) stated that universal recommendation of 100 kg Urea and 100 kg DAP/ha should not be an option as best production package for all barley growing areas. Hence, the current result considering multi-nutrient treatments for specific crop and location can be best option for barley production. Woubshet *et al*., (2017) have also reportedthat NPSB fertilizer combined with lime, compost and KCl increased grain yield of barley. According to these authors application of 0.611 t lime + 2.5 t compost + 75 kg NPSB + 50 kg KCl and 36 kg/ha N significantly improved barley grain yield (Woubshet *et al*., 2017). The plant height and above ground total fresh biomass yield also were significantly influenced by the applied fertilizers, where the lowest values for both parameters were recorded for the T1 and T 2 (Table 1). The higher vegetative growth and grain yield obtained from fertilizer treated plots might be due to adequate and balanced supply of nutrients from the soil to the plants. This result is in line with Landon (1991), who reported that plant growth and development would be retarded if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements. The addition of P fertilizer did not have a significant impact on number of tillers and spike length of barley.

3.1 Economic analysis

The dominance analysis showed that except treatment 5, 6 and 7 all other treatments were dominated by the treatment with lower variable cost and higher net benefit (Table 2). Treatment 6 hadlower total variable cost (TVC) and higher net benefits than did thetreatment with the next lowest total variable cost (treatments 2).

Table 2 Economic (partial budget and dominance) analysis of fertilizers for barleyproduction in Bule woreda

Tr	NPSB (kg/ha)	NPS (kg/ha)	Urea kg/ha	KCl kg/ha	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1	0	0	0	0	3409.0	3068.1	0.0	32215.05	32215.1	
6	150	0	41	100	4605.9	4145.3	3301.0	43525.76	40224.8	
2	0	142	42	100	4332.4	3899.2	3321.6	40941.18	37619.6	D
7	200	0	72	100	5158.0	4642.2	4086.5	48743.10	44656.6	
3	0	189	72	100	4839.0	4355.1	4098.7	45728.55	41629.9	D
5	0	142	159	100	5271.9	4744.7	4346.0	49819.46	45473.4	
9	150	0	161	100	4870.4	4383.4	4351.6	46025.28	41673.6	D
8	250	0	102	100	4812.1	4330.9	4863.2	45474.35	40611.1	D
4	0	237	102	100	4815.6	4334.0	4886.7	45507.42	40620.8	D

Tr= Treatment, Yield adjustment =10%, field price of barley = 10.5 Ethiopian Birr/kg, official price for urea- N = 8.75 Ethiopian Birr/kg, NPS fertilizer = 10.9 Ethiopian Birr/kg, NPSB fertilizer = 10. 3 Ethiopian Birr/kg,potassium chloride-K = 14 ETB/kg, TVC = total cost that varies, NB = net benefit, D indicates dominated treatments that are rejected, MRR = marginal rate of return.

T 7 had lower total variable cost and gave high net benefit compared to treatment 3. And T5 had lower total variable cost and gave higher net benefit than did treatment 4, 8 and 9. Based on the dominance analysis, treatments 5, 6, and 7 were found to be potential options (Table 2). Therefore, treatments 2, 3, 4, 8 and 9 were eliminated and only the dominant treatments were considered for further partial budget analysis (Table 3).

Table 3 Economic (partial budget and marginal rate of return) analysis of fertilizers forbarley production inBuleworedu

Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1. No fertilizer	3409.0	3068.10	0.0	32215.05	32215.1	
6. NPSB: 46,23.5,10, 1.07 + 50K	4605.9	4145.31	3301.0	43525.76	40224.8	243
7. NPSB: 69,31,13, 1.4 + 50 K	5158.0	4642.20	4086.5	48743.10	44656.6	564
5. NPS: 92, 23.5, 10 + 50 K	5271.9	4744.71	4346.0	49819.46	45473.4	315

Yield adjustment =10%, field price of barley = 10.5 Ethiopian Birr (ETB)/kg, official price for urea-N = 8.75ETB/kg, NPS fertilizer = 10.9 ETB/kg, NPSB fertilizer = 10. 3 ETB/kg, potassium chloride-K =14 ETB/kg, TVC = total cost that varies, NB = net benefit, MRR = marginal rate of return.

The partial budget analysis, showed that treatment with the higher net benefit (45,473ETB/ha) and acceptable marginal rate of return (315) was T5 as compared to T6 and T7, which gave 40,225ETB and 44,656 ETB/ha net benefit, respectively with %MRR of 243 and 564%, respectively (Table 3). This means that, for each 1 ETB investment, the producer can get 3.15, 2.3 and 5.64 ETB from T5, T6 and T7, respectively, and can be accepted as the potential options for barley producing farmers in the study area.

3.2 Sensitivity analysis

As market prices are ever changing, recalculation of the partial budget considering future prices would be necessary to identify treatments which can remain stable and sustainacceptable returns for farmers, despite input price fluctuations. In the present study, with theprojected increament of fertilizers by 20% because of changes in the exchange rate and transportation costs, feasibility analysis revealed that T5, T6 and T7 would give sustainable and an acceptable returns for farmers in the future.

Table 4 Partial budget analysis at projected future prices of NPS, NPSB and urea fertilizersfor barley production in Bule woreda

Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1. No fertilizer	3409.0	3068.10	0.0	32215.05	32215.1	
6. NPSB: 46,23.5,10, 1.07 + 50 K	4605.9	4145.31	3961.2	43525.76	39564.6	186
7. NPSB: 69,31,13, 1.4 + 50 K	5158.0	4642.20	4903.8	48743.10	43839.3	454
5. NPS: 92, 23.5, 10 + 50 K	5271.9	4744.71	5215.2	49819.46	44604.2	246

Yield adjustment =10%, field price of barley = 10.5 Ethiopian Birr (ETB)/kg, official price for urea-N = 8.75ETB/kg, NPS fertilizer = 10.9 ETB/kg, NPSB fertilizer = 10. 3 ETB/kg, potassium chloride-K = 14 ETB/kg, TVC = total cost that varies, NB = net benefit, MRR = marginal rate of return.

3. Conclusion and Recommendation

Results of the present study revealed that application of fertilizers had significant effect on barley production. Exclusion of B did not significantly affect barley growth and yieldcomponents. Significantly higher grain yield of barley was recorded from T5 (NPS at 92, 23.5, 10 kg/ha + 50 kg K) followed by T7 (NPSB: 69, 31, 13, 1.4kg/ha) compared to treatment 2 and 1. The highest gain yield and net benefit was obtained by applying NPS at92 kg N, 23.5 kg P and 10 S kg + 50 kg K/ha with acceptable marginal rate of return (246%). Although application of NPSB at 46 kg N, 23.5 kg P, 10 kg S, 1.07 kg B/ha and 69 kg N + 31 kg P + 13 kg S +1.4 kg B/ha also gave the required return even under the projected input price, statistically did not differ from similar rates of NPS, suggesting lower impact of B on barley. It is, therefore, concluded that application of NPS at 92 kg N, 23.5 kgP, 10 kg S and 50 kg K/ha improve barley yield and benefit farmers in Bule wereda and hence recommended for barley production. However, future field trials are required on evaluating the influence of individual nutrients along with their compound formulations and RNP on crop performance to avoid confounding effects.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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