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Effect of NPS and NPSB Fertilizers and their Rates on Yield and Yield Components of Barley in Gedeb, Southern Ethiopia

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Abstract

Improving the use of balanced nutrition based on actual limiting nutrients for specific site is a crucial issue for sustainable barley production in South Nations Nationalities and People Ronal State (SNNPRS). On farm experiment was conducted on two farmers' field in 2016 and 2017 cropping seasons to validate NPS and NPSB blended fertilizers and determine their rates for barley production in Gedeb woreda of SNNPRS. 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. In addition, except the absolute control all plots received 50 kg K/ha. Results of two years combined analysis indicated that all fertilizer treatments significantly ($P \leq 0.05$) increased grain yield and yield components of barley. Significantly ($P \leq 0.05$) higher grain yield was obtained from application of T5 (NPS at 92 kg N, 39 kg P and 17 kg S/ha) as compared to the T1 and T6. The inclusion of B in NPS had no or negative effect on barley yield at Gedeb. The yield advantage of T5 over T1 was 165%. The highest net benefit with acceptable marginal rate of return (112%) even with a projected input price was also obtained from T5. Thus, application of NPS at 92 kg N, 39 kg P and 17 kg S/ha could be recommended as the best option for barley production around Gedeb and similar soil type and agroeclogies. However, further research is need on individual macro and micro element to identify effect of each nutrient on crop and to verify and demonestrethe finding for wider use.

Keywords: Blended Fertilizer, Economic Feasibility, Fertilizer Rates, Grain Yield

Introduction

Barley *(Hordeumv ulgare 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) [10]. In Ethiopia, barley is ranked fifth of all cereals in area of production, but third in yield per unit area (CSA, 2004) [7]. Although barley is the most important cereal crop, its productivity remained low at below 1.3 t/ha (CSA, 2004) [7], whereas the potential yield goes up to 6 t/ha on experimental plots (Berhane *et al*., 1996) [3]. Soil fertility is the most limiting factor for barley production in the highlands of Ethiopia (Woldeyesus and Chilot, 2002) [19]. Due to undulating nature of the land in these areas, the soil is washed away every year. Besides continuous cropping, high proportion of cereals in the cropping system, and application of suboptimal levels of mineral fertilizers also aggravate the decline in soil fertility (Tanner *et al*., 1991) [17]. In addition, limited availability of organic matter inputs; removal of crop residues from farm lands due to its increasing demand for fuel and fodder, and lower biomass production driven by declining soil fertility and competing uses are also leading to continuous nutrient mining from the soil (Selamyihun *et al*., 2005, Nigussie *et al*., 2007) [16, 14].

Farmers in the country, in general and in the region (SNNPRS), in particular use inorganic and organic inputs to counteract crop 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) [6], the intensity of fertilizer use has increased only marginally over the past decade from 31 kilograms/ha in 1995 to 36 kilograms/ha in 2008 which was still less than the blanket recommendation whereas fertilizer factor productivity declined by 63% during the same period (Alem *et al*., 2008) [2].

Nutrient mining due to sub optimal fertilizer use, in one hand, and unbalanced fertilizer (only N and P) uses, on the other, have favored the emergence of multi nutrient deficiency in Ethiopian soils (Abyie *et al*., 2003) [1]; which in part may 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) [8], all of which 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 with the increasing problem of multi nutrient deficiencies.

To this end, the use of balanced fertilizers involving all or most of the nutrients required by plants would be important to ensure sustainable high crop production. Experience in Malawi provides shows a striking example of how N fertilizer efficiency for maize can be raised by providing appropriate micronutrients on a location-specific basis, where supplementation by S, Zn, B, and K increased maize yields by 40% over the standard N-P recommendation alone (John *et al*., 2000) [11]. The work of Wassie and Shiferaw (2011) [18] in southern Ethiopia also shows how fertilizer use efficiency of potato could be raised when NP fertilizers were combined with K on a location-specific basis. In their study, it has also been observed that supplementation of K increased potato tuber yields by 197% over the standard N-P recommendation alone (Wassie and Shiferaw, 2011) [18]. Therefore, it is high time to investigate nutrient dynamics in major production systems and establish site, crop and soil specific balanced fertilizer recommendation. 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, and Agro-ecological Zones. Although the need for site-specific fertilizer prescriptions is becoming increasingly important for enhanced crop production, fertilizer trials involving multi-nutrient blends that include micronutrients are rarein the country. Therefore, this study was initiated to provide site and crop specific balanced fertilizer recommendations for better barley production in Gedeb woreda of SNNPRS.

Materials and Methods

A field experiment was conducted to evaluate different blended fertilizers for barley production in Gedebworeda of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS) in the main cropping seasons of 2016 and 2017. Treatments were prepared based on the nutrient deficiency of the area as indicated in the soil fertility map of the region produced by Agricultural Transformation Agency (ATA, 2016) [13]. Accordingly, two types of fertilizers (NPS and NPSB) were used in different rates. The experiment consisted of nine treatments: *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 arranged in a randomized complete block design with three replications. In addition, except the absolute control, all plots received 50 kg K/ha as potassium chloride (KCl). The recommended N rate was adjusted by using urea.

Experimental layout

The experiment was conducted on two farms in each year and laid out in a randomized complete block design with three replications and 4 m by 4 m plot size. The spacing 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 adjustment 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 other field management practices were used as recommended for the crop.

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, number of tillers per plant and spike length data was taken from randomly selected five plants.

Agronomic and partial budget analysis

Collected data were subjected to Analysis of variance (ANOVA) using Proc GLM procedures of SAS 9.3 version 5 (SAS, 2002) [15]. Least significant difference (LSD) at 5% probability level was used to separate mean values of treatments for each parameters whenever significant difference between means occurred.

Partial budget analysis

Economic analysis was also carried out to evaluate economic feasibility of the rates fertilizers (NPS and NPSB) for barley production in Gedeb. For partial budget analysis, average yield was adjusted downwards by 10%, assuming that farmers would get about 10% less yield than is achieved on an experimental field. The average open market price for barley was 10.5 Ethiopian Birr (ETB)/kg) and the official price for NPS, NPSB, KCl and Urea was 10.94, 10.28, 14 and 8.76 ETB/kg, respectively. All other costs incurred for farm operations were considered the same for all plots. For a treatment to be considered a worthwhile option for farmers, the minimum acceptable marginal rate of return should be over 50% (CIMMYT, 1988) [5]. However, Gorfu *et al*. (1991) [9] have suggested that a minimum acceptable rate of return should be 100%. Therefore, the minimum acceptable marginal rate of return considered in this study was 100%.

Results and Discussion

Results of the combined analysis of two years indicated that the fertilizer treatments significantly ($P \leq 0.05$) increased growth and yield parameters of barley over untreated control (Table 1). Application of NPS had similar effect on all tested barley parameters with that of NPSB. The inclusion of B in NPS had no or negative effect on barley yield at Gedeb. Except for biomass yield, highest values for plant height, number of tillers and grain yields was recorded from treatment 4 (NPS at 92 kg N, 39 kg P, 17 kg S/ha). Significantly ($P < 0.05$) highest grain yield was obtained from treatment 4 as compared to T6 and T1 but on par with other treatments. All other rates of the two fertilizers appeared to have similar effects on barley yield at Gedeb district. The yield advantage of T4 over the T1 was 165% (Table 1).

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

Treatments	Plant height (cm)	No of tillers/plant	Spike length (cm)	Biomass yield t/ha	Grain yield kg/ha
1. No fertilizer	67.08b	5.3c	5.73d	3.1c	1181.6c
2. NPS: 46+23.5+10 kg/ha	81.40a	8.7ab	6.76bc	6.1ab	2688.4 ab
3. NPS: 69+31+ 13 kg/ha	83.80a	9.7ab	7.06ab	6.3ab	2641.9 ab
4. NPS: 92+39+ 17 kg/ha	84.80a	10.6a	7.27a	6.6 ab	3131.6 a
5. NPS: 92+23.5+ 10 kg/ha	83.23a	9.4ab	7.09a	6.2ab	2618.7 ab
6. NPSB: 46+23.5+10+ 1.07 kg/ha	81.55a	8.6b	6.73c	5.5b	2500.1 b
7. NPSB: 69+31+13+ 1.4 kg/ha	82.88a	9.6ab	7.06ab	6.1ab	2714.7 ab
8. NPSB: 92+39+17+ 1.7 kg/ha	82.83a	9.8ab	7.08a	6.9a	2790.4 ab
9. NPSB: 92+23.5+ 10+1.07 kg/ha	80.77a	8.8ab	6.98abc	5.7ab	2606.4 ab
LSD at 0.05	5.44	1.93	0.314	1.40	577.03
V(%)	5.61	6.69	6.69	19.68	27.73

Means followed by same letter (s) with in a column are not significantly different at $P < 0.05$

As investigation on blended fertilizers is at infant stage in the region as well as in the country, direct research out puts which can support the current result is very limited. However, the response of barley to bio-slurry compost and chemical fertilizer has been studied in Tigray region from 2001–2005, and it has been observed that the use of chemical fertilizer gave a yield advantage of 36.7% over the control (Birhan Abdulkadir *et al.*, 2017) [4]. The same authors have also reported that, at Waza, Hintalo Wejerat, application of chemical fertilizer increased grain yield of barley by 42% compared to the control.

Similarly, number of tillers/plant, plant height, spike length and total above ground biomass yield were significantly influenced by the applied fertilizers. Tiller numer per plant followed the same trend with grain yield. There were no significant differences between fertilizer types and among theirs rate on plant height. T4 had significant effect on tiller density compared to T1 and T6, whereas T4, T5 and T7 had significant effect on spike length as compared to T1, T2 and T6. The lowest value for all the parameters were recorded for the untreated plot (Table 1). According to Landon 1991, 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. Therefore, the higher vegetative growth with application of blended fertilizers in the present study might be due to adequate and balanced nutrient supply to the soil.

Economic analysis

Results of partial budget analysis showed that treatment with the higher net benefit was T4 (23,298ETB/ha) compared to T2 and T6 that gave 20,874 ETB and 19,200 ETB/ha net benefit, respectively (Table 3). However, the marginal rates of return for treatments 2 and 6, were 811 and 259%, respectively, while that of T4 was 155%, suggesting that 1 ETB investment could reward more than 100%.

Table 2: Economic (partial budget and dominance) analysis of fertilizers for barley production in Gedeb woreda

Tre	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	1181.6	1063.4	0.0	10634.4	10634.4	
6	150	0	41	100	2500.1	2250.1	3301.2	22500.9	19199.7	
2	0	142	42	100	2688.4	2419.6	3321.8	24195.6	20873.8	
7	200	0	72	100	2714.7	2443.2	4086.7	24432.3	20345.6	D
3	0	189	72	100	2641.9	2377.7	4098.9	23777.1	19678.2	D
5	0	142	159	100	2618.7	2356.8	4346.2	23568.3	19222.1	D
9	150	0	161	100	2606.4	2345.8	4351.8	23457.6	19105.8	D
8	250	0	102	100	2790.4	2511.4	4863.4	25113.6	20250.2	D
4	0	237	102	100	3131.6	2818.4	4886.9	28184.4	23297.5	

Tre= treatment, Yield adjustment =10%, field price of barley = 10 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 variable cost, NB = net benefit, D indicates dominated treatments that are rejected, MRR = marginal rate of return.

Table 3: Economic (partial budget and marginal rate of return) analysis of fertilizers on barley at Gedeb

Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1. No fertilizer	1181.6	1063.4	0.0	10634.4	10634.4	
6. NPSB: 46,23.5,10, 1.07	2500.1	2250.1	3301.2	22500.9	19199.7	259
2. NPS: 46,23.5,10	2688.4	2419.6	3321.8	24195.6	20873.8	811
4. NPS: 92, 39, 17	3131.6	2818.4	4886.9	28184.4	23297.5	155

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

Since the minimum acceptable rate of return assumed in this experiment was 100%, all these treatments (4, 2 and 6) can give an acceptable marginal rate of return for the extra investment. Therefore, treatment 2, 4 and 6 could be accepted as the potential options for barley producing farmers in the area.

Sensitivity analysis

It would be important to calculate again the partial budget based on expected changes in the market price of inputs in the future. This would help to pinpoint treatments which can remain stable and sustain acceptable returns for farmers, despite future input price fluctuations. In the present study,

it was assumed that the official price of NPS, NPSB, urea and potassium fertilizers will increase by 20%. The assumption of price increment in these fertilizers emanated mainly from the change in the exchange rate and cost of transportation. Hence, based on the sensitivity analysis (Table 4), T2 (NPS at 46 kg N, 23.5 kg P and 10 kg S/ha), 4 (NPS at 92 kg N, 39 kg P, 17 kg S/ha)) and 6 (NPSB at 46 kg N, 23.5 kg P, 10 kg S and 1.07 kg B/ha) would give an economic yield response and also sustain acceptable returns even under 20% input price increment farmers likely face in the future. Therefore, these treatments could be worthwhile for farmers.

Table 4: Partial budget analysis at projected future prices of NPS, NPSB and urea fertilizers for barley production in Gedebworeda

Treatments (kg/ha)	Av. Yield	Adj. yield	TVC (EB/ha)	Revenue (EB/ha)	NB (EB/ha)	MRR (%)
1. No fertilizer	1181.6	1063.4	0.0	10634.4	10634.4	
6. NPSB: 46,23.5,10, 1.07	2500.1	2250.1	3961.4	22500.9	18539.5	200
2. NPS: 46,23.5,10	2688.4	2419.6	3986.2	24195.6	20209.4	674
4. NPS: 92, 39, 17	3131.6	2818.4	5864.2	28184.4	22320.2	112

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

However, when biological grain yields, net benefits and MRR% obtained by application of equal rates of NPS and NPSB (at 46 kg N, 23.5 kg P and 10 kg S/ha and 46 kg N, 23.5 kg P, 10 kg S and 1.07 kg B/ha) were compared, they were higher by application of NPS at 46 kg N, 23.5 kg P and 10 kg S/ha which validates the use of NPS at the study site.

Conclusion and Recommendations

The present study clearly showed that both fertilizer types and their rates significantly influenced barley production compared to the control. However, no significant differences obtained between the two fertilizer types and among their rates, suggesting that inclusion of B in NPS fertilizer had no effect on barley yield at Gede. The highest grain yield was obtained from application of NPS at 92 kg N, 39 kg P, 17 kg S/ha. Similarly, the highest net benefit (ETB 22320.2) with acceptable marginal rate of return (112%) was obtained from NPS at the same rate, even with the projected input price. Application of NPS at 46,23.5,10 also improved barley yield significantly and would sustain the required economic return at 20% input price increment, as it exhibited more than 100% MRR considered in this experiment. However, treatment 4 resulted in more than 10.5% net benefit than did treatment 2. Therefore, applying NPS at 92 kg N, 39 kg P, 17 kg S/ha (237 kg NPS + 100 kg N and 100 kg KCl kg/ha), could be recommended as the best option for barley producers around Gedeb and similar areas. The use of NPS at 46, 23.5, 10 kg/ha could also be recommended as another option for resource poor farmers in the area. In the current experiment, compound form of NPS and NPSB fertilizers were used and, thus, separate effect of each nutrient was not evaluated. Furthermore, the treatment set up of the experiment lacked positive control (recommended NP) to compare against the newly imported NPS and NPSB fertilizers. Therefore, future field trials should consider the influence of individual nutrients along with their compound formulations comaring against recommended NP on crop performance to avoid confounding effects.

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