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Effect of NPS and Nitrogen Fertilizer Rate on Yield and Yield Components of Food Barley (*Hordeum vulgare* L.) in Western Oromia, Ethiopia

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Abstract: Inappropriate crop management practices are among the key elements contributed to low productivity of Barley. Moreover, application of balanced fertilizers and nutrient requirements of the crop is the basis to produce more crop yield from the land under cultivation. Accordingly, field experiment was conducted in 2018 & 2019 main cropping season from the mid of July to first of December at Gedo and Shambu research station to identify the optimum amount of NPS and N fertilizer rate and to evaluate the economic profitability of NPS and N fertilizers for Barley production. The experiment was consisted of twenty treatments combined factorial with five NPS (75, 87.5, 100, 112.5 and 125 kg ha-1) and four Nitrogen (17, 23, 29 and 35 kg ha-1) rates keeping the other managements and cultural practices uniform. The experiment was laid out in randomized complete block design with three replication. The pre soil analysis indicated that the soil of experimental area is acidic (pH = 4.99 at Gedo and 4.98 at shambu) and low in available Phosphorus (12 ppm at Gedo and 13 ppm at Shambu). The main effect of days to heading, grain per spike, thousand seed weight and harvest index were not significantly (P>0.05) influenced due to NPS and N rate. Whereas, days to maturity, plant height and panicle length were significantly different (P<0.05) due to the main effects of N rates though not influenced due to NPS rates at Gedo and Shambu. On the other hand, number of effective tiller, grain yield and above ground biomass were highly significantly (P<0.01) influenced due to the main and interaction effect of NPS and N rates at both locations. Among different NPS and N fertilizer rates tested, the combination of 125 NPS and 35 N kg ha-1 rates gave the highest yield thereby resulting in the highest net benefit. Thus, economic analysis indicated that combination of 125 NPS (47.5 P_2O_5, 23.75 N, 8.75 S kg ha-1) and 35 N kg ha-1 rates on HB -1307 variety gave grain yield (3631.79 kg ha-1) with the net benefit (39849.01 birr/ha) and the highest marginal rate of return (992.16%) are economically feasible alternative to the other treatments. Therefore it is advisable to use combination of 125 NPS and 35N kg/ha rates on HB -1307 variety since economically feasible to the farmers. However, to reach at conclusive idea there is future line of work to get the peak point at which this fertilizer combination showed turning point.

Keywords: Economic Analysis, NPS Rates, Yield and Yield Components

1. Introduction

1.1. Background

Barley (*Hordeum vulgare*) is among the important cereal crops cultivated in Ethiopia. It occupies 0.951 million ha of land and is ranked 5th in terms of production area [7]. It is grown in diverse environments at an altitude range of 1500–3500 m.a.s.l, but predominantly at 2000–3500 m.a.s.l. Barley was the staple food of people in many countries for ages, but it drew away from favor due to changes in food preferences. It is the fourth most important cereal crop in the world after wheat, maize, and rice, and is among the top ten crop plants in the world [9]. In Ethiopia, barley grain is produced mainly for human consumption and it is one of the most important staple food crops [4]. The majority of barley that farmers grow is food barley and it is the main ingredient for several staple dishes such as injera, porridge and bread. It is mostly used for feed and fodder besides being a significant crop industrially, particularly in the manufacture of beer.

Barley covered an area of (951,993.15) hectare and has national average yield of 2157 kg per hectare [7]. Ethiopia experiences one of the highest rates of soil nutrient depletion in sub-Saharan Africa. The estimated annual nationwide loss of phosphorus and nitrogen resulting from the use of dung and crop residues for fuel is equivalent to the total amount of commercial fertilizer being [13]. The most important abiotic stresses include low soil fertility, low soil pH, poor soil drainage, frost and drought. Soil degradation is one of the major challenges to improved agricultural production and food security in the country. Hence, poverty reduction and achieving food security is among the prime policy agenda of the Ethiopian government.

The ratio of total area under barley to other cereal crops (including wheat, teff, maize and sorghum) has been decreasing over the past 25 years. The reduction in the area under barley in the recent past could be attributed to a number of factors, including that most of the area under barley is sown to farmer cultivars. Fertilizer use on barley is the lowest among all cereals, which evidently seen, in the 2005 main cropping season, only 16.48% of land of the total area covered by cereals received inorganic fertilizer. When the total area covered with teff, wheat and maize received 25.13, 25.60 and 17.74% of fertilizer, respectively; barley received only 6.92% of the fertilizer for the total area in the same year [6]. In other cases according to AGP II constraint survey, the cost of fertilizer is becoming unaffordable particularly by subsistent farmers. As a result, majority of farmers use fertilizer below the recommended rates and every farmer applied different rate of fertilizers.

Di-ammonium Phosphate (DAP: P_2O_5 46% and N 18%) and urea ($CO(NH_2)_2$): N 46%) are the two main source of mineral fertilizer that have been recommended for use in cereal production in Ethiopia. According to soil fertility status atlas of Ethiopia [11] available sulfur, and extractable iron, zinc and boron are deficient. Of all those production bottle necks, much hope has been vested on the agricultural sector to provide enough produce to meet the food demand of increasing population by raising the productivity of smallholder agriculture through intensive use of inputs (mainly improved seeds and fertilizers), and agricultural extension services. The application of fertilizer also needs site specific prescription since soils in different area are highly heterogeneous in nutrient status, pH, nutrient holding capacity and other chemical properties. In addition, no work has been done to evaluate NPS and Nitrogen fertilizer rate that boost yield and yield components of barley. Therefore the study is aimed to investigate the effect of NPS and nitrogen fertilizer rate on the yield of barley with the objectives to identify the optimum amount of NPS and N fertilizers for Barley and to evaluate the economic profitability of NPS and N fertilizers for Barley production.

1.2. The Objective of the Study

1) To identify the optimum amount of NPS and N fertilizers for Barley production.
2) To evaluate the economic profitability of NPS and N fertilizers for Barley production.

2. Materials and Methods

The trial was conducted at sub- station of Bako Agricultural research center at Gedo and Shambu locations. During under taking the experiment different rate of NPS and Nitrogen rate for Barley were assessed. Five rates of NPS (75, 87.5, 100, 112.5 and 125 kg/ha NPS) and Four rates of Nitrogen (17, 23, 29 and 35 Kg/ha N) were done in factorial combination. Blanket recommendation of 100 kg/ha NPS and 46kg/ha UREA was included as check in the experiment during conducting the trial. All the NPS Fertilizer was applied during planting time and urea was applied in splits half at planting and the remaining half at tillering. The trial was laid out with three replications under completely randomized block design. The land preparation was done thoroughly ahead of planting time and Seed of Barley variety (HB -1307) was sown in six rows with 20 cm between rows and 1.5m between block and 1m between plots respectively. Gross plot area of the plots accommodated 1.2 m length and 2.5m width ($3m^2$). A composite soil sample was taken before onset of rainfall from the selected area of the intended sub-site and analysed for nutrient status of the soil.

3. Data Collection and Measurements

3.1. Growth, Yield and Yield Component

Days to 50% emergence was recorded when days from sowing to the seedlings comes on 50% emergence among a plot. Similarly, Days to heading was determined when 50% of the plants started to emerge the tip of panicles. Days to Physiological maturity was recorded as the number of days from date of sowing till in 90% of the plants changed their green color to yellowish, in each plot, Plant height (cm) was recorded by measuring the length of individual culms of ten plants from the soil surface to the tip of the spike and the average was calculated. Number of productive tillers were obtained by counting the numbers of productive ear bearing tillers of the ten randomly selected plants and the average was taken. Panicle length (cm) was recorded by measuring the length of spike of ten plants from the spike collar to the tip of the spike (excluding the awns) and the average was calculated. Thousand kernel weight (g) was taken randomly from whole grains and counted using a seed counting machine until thousand seed was obtained and finally adjusted to using the standard moisture. Finally, Grain yield (kg) harvested from the net area was threshed, cleaned and weighed and adjusted according to the standard moisture content of the crop and Biomass yield harvested by cutting all the above-ground biomass within the harvested area, dried to constant moisture content and weighed and converted to kg/ha.

3.2. Data Analysis

The data obtained from the field were subjected to analysis of variance (ANOVA) using SAS, version 9.0, General linear model procedures SAS Institute [15] and mean separation was by least significant difference (LSD) test.

4. Results and Discussions

4.1. Soil Physico-Chemical Properties of Experimental Site

The soil textural classes consisted the proportion of 46% sand, 36% clay and 18% silt indicating sand clay at shambu and 40% sand, 54% clay and 6% silt depicted clay at Gedo. The soil pH was highly acidic (4.98 at shambu and 4.99 at Gedo) which is in line with EthioSIS [10] rating, pH ranges 4.5 to 5.5 is highly acidic. The total nitrogen value of the experimental soil was medium (0.21 and 0.3) at Gedo and shambu respectively, which agrees with EthioSIS [11] rating, soil total nitrogen content 0.15-0.3 rated as medium. The organic carbon of the soil showed medium (4%) at shambu and low (2.42%) at Gedo that agrees with Tekalign [19] rating, organic matter content of the soil is very low (<0.86%), low (0.86 to 2.59), medium (2.59 to 5.17) and high (>5.17) while the available phosphorus indicated that there was low phosphorus content of the soil (13 at shambu and 12 mg/kg at Gedo) which coincides with the rating of Bray (1945), the range of phosphorus in Bray method is <7, 8-19, 20-39, 40-58 and >59 was very low, low, medium, high and very high, respectively. This implied that sufficient phosphorus supply is necessary to the study area.

4.2. Growth, Yield and Yield Components

From the analysis of variance Days to heading, Grain per spike, Thousand seed weight and harvest index were not significantly influenced due to the main and interaction effect of NPS and Nitrogen rates (p>0.05). However, plant height, Days to maturity and Panicle length were positively responded (p<0.05) due to the main effects of Nitrogen rates even if not significantly different with NPS rates (p>0.05) on the tested locations of shambu and Gedo (Table 1). The highest Days to maturity (135 days) was recorded at the highest nitrogen rates (35 kg ha^{-1}) might be due to the deleyance in growth during vegetative stage. In similar ways, the highest plant height (93.4 cm) and panicle length (8.41) were recorded at the highest rates of nitrogen (35 kg ha^{-1}) (Table 1). This result is in line with [8] who reported the highest days to maturity and plant height were recorded at wheat varieties. Similarly, [18] and [17] reported significant increments in plant height due to application of high nitrogen rate.

Table 1. *The main effect of rates of NPS and Nitrogen on Days to Heading, Days to maturity, Plant height, Grain per spike, Thousand seed weight, Harvest Index and Panicle length of food barley (HB-1307).*

Treatments	DH	DM	PH	GPS	TSW	HI	PL
NPS rates (kg ha^{-1})							
75	61.92	134.46	91.38	55.01	42.88	42.43	7.958
87.5	61.96	134.71	92.32	54.96	43.92	44.53	7.996
100	61.40	134.77	92.50	56.62	43.41	44.25	8.100
112.5	61.12	134.15	91.70	56.32	43.24	43.29	8.237
125	61.12	134.08	91.26	56.78	43.89	44.15	8.098
LSD	ns	ns	ns	ns	ns	ns	ns
N Rates (kg ha^{-1})							
17	61.67	134.3 ab	91.66 bc	56.26	43.78	43.68	8.028 b
23	61.87	134.5 ab	90.27 c	54.96	43.67	44.34	8.032 b
29	61.02	133.9 b	91.99 ab	55.66	43.08	43.10	7.847 b
35	61.47	135.0 a	93.40 a	56.87	43.35	43.80	8.405 a
LSD	ns	0.74	1.60	ns	ns	ns	0.337
CV	3.6	1.5	4.8	9.5	6.1	12.2	11.6

On the other hand, the Number of effective tiller, Grain yield and Above ground biomass were highly significantly different (p<0.01) due to the main and interaction effect of NPS and Nitrogen rates at Gedo and Shambu locations (Table 2). The highest number of effective tillers (5.7) were observed from the combination of the 100 NPS and 35 kg ha^{-1} nitrogen rate followed by the interaction of 125 NPS and 35 kg ha^{-1} nitrogen rate. This might be associated with when plant nitrogen demand met more tillers flushes from the main tillers providing productive tillers for better yield of the crop. The result in line with [8] who reported the response of the crop in terms of number of effective tillers in Kingbird (6.0) wheat varieties were higher at 300 Kg of NPSB application with supplementary urea. The results are in agreement with that of [2] who reported that increasing in the number of effective tillers with nitrogen fertilization. [3, 1] also reported that nitrogen fertilization have significant effect on effective number of tillers of wheat. However, the smallest number of effective tillers were recorded from 112.5 kg ha^{-1} NPS and smallest rates of nitrogen (17 kg ha^{-1}) which might be connected with less nitrogen supply results less initiation of the tillers (Table 2).

Table 2. *The interaction effects of Nitrogen and NPS rates on Number of effective tiller of food barley (HB-1307) at Gedo and shambu locations.*

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	**87.5**	**100**	**112.5**	**125**
17	4.917 bcdef	5.333 abcd	5.383 ab	4.250 g	4.717 cdefg
23	4.607 efg	5.133 abcdef	5.700 a	5.367 abc	5.150 abcdef
29	5.142 abcdef	5.150 abcdef	4.667 efg	4.550 fg	4.627 efg
35	5.383 ab	5.037 abcdef	4.673 defg	5.267 abcde	5.633 a
LSD	0.663				
CV	16.3				

As Grain yield is directly related to the number of productive tillers, it was positively responded to the interaction effects of NPS and nitrogen rates as well (Table 3). The highest grain yield (4026 kg ha^{-1}) was obtained from the combination of the highest rates of 125 NPS and 35 kg ha^{-1} nitrogen followed by (3716 kg ha^{-1}) grain yield which was resulted from the interaction of 100 NPS and 35 kg ha^{-1} nitrogen (Table 3). The highest grain yield at the highest rates of NPS and nitrogen might be connected with provision of adequate plant nutrient requirement resulting the induction of more productive tillers which directly correlated with the production of better yields. In line with the results, [14] indicated that higher response of yield to Nitrogen application may indicate the growth and yield enhancing attributed due to synchrony between the time of high need of the plant for N uptake and the time of availability of sufficient N in the soil at the specified growth stages. Likely, [20] reported that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increase the grain yield by 48 kg ha^{-1}. In the same way, [12] also found that a positive reaction of N and S fertilization provide the highest grain yield (54 kg ha^{-1}). Conversely, the lowest grain yield (2967 kg ha^{-1}) was resulted when smallest NPS rates (75 kg ha^{-1}) associated with 23 kg ha^{-1} nitrogen (Table 3).

Table 3. *The interaction effects of Nitrogen and NPS rates on Grain yield of food barley (HB-1307) at Gedo and shambu locations.*

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	**87.5**	**100**	**112.5**	**125**
17	3176 efgh	3410 bcdef	3374 bcdefg	3283 defgh	3167 efgh
23	2967 h	3127 fgh	3561 bcd	3127 fgh	3381 bcdefg
29	3124 fgh	3484 bcde	3052 gh	3322 defg	3412 bcdef
35	3333 cdefg	3292 defgh	3716 ab	3681 abc	4026 a
LSD	353.6				
CV	13.1				

In similar ways to grain yield, the highest above ground biomass (9089 kg ha^{-1}) was resulted when 125 NPS and 35 kg ha^{-1} rates of nitrogen interacted together at the tested sites. Similarly, comparative above ground biomass (8269 kg ha^{-1}) was obtained from the combination of 112.5 NPS and 35 kg ha^{-1} nitrogen (Table 4). This might be related to vigorus vegetative growth of the crop as a result of addition of adequate crop nutrient to the soil desired by plants and alleviates the limitations of improper growth. Likely, supply of micronutrients like sulfur may increase the flush of more tillers which attributed to development of high above ground biomass. This result agreed with the finding of [20] who found that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increased the biomass by 115 kg ha^{-1}. This was due to Sulfur enhanced the formation of chlorophyll and encouraged vegetative growth and B helps in N absorption. On the other hand, the smallest above ground biomass (6518 kg ha^{-1}) was recorded from the combination of 75 NPS and 23 kg ha^{-1} Nitrogen rates. The results agreed with [16] that reported the straw and grain yield were the lowest for lowest nitrogen treatment.

Table 4. *The interaction effects of Nitrogen and NPS rates on Above ground biomass yield of food barley (HB-1307) at Gedo and shambu locations.*

N Rates (kg ha^{-1})	NPS rates (kg ha^{-1})				
	75	**87.5**	**100**	**112.5**	**125**
17	7444 bcdef	7203 bcdef	7637 bcde	7507 bcdef	7345 bcdef
23	6518 g	6835 efg	7980 bc	6873 def	7304 bcdef
29	7237 bcdef	7935 bcd	6748 fg	7451 bcdef	7711 bcde
35	7940 bcd	7165 cdef	8152 abc	8269 ab	9089 a
LSD	846.0				
CV	13.9				

4.3. Economic Analysis

The experiment was conducted with two factor experiments including different NPS and Nitrogen rates combined factorally by keeping all cultural managements uniformly. Thus, the partial budget analysis was done on the basis of total variable cost considering the costs of different NPS, Nitrogen rates and transport as well as application costs. The economic analysis was done on the basis of adjusting 10% yield downward for fact that it closest to the farmer yield. The result of partial budget analysis showed that from twenty treatment tested six treatments (NPS and N rates combination) were non-dominated with an associated MRR greater than 100% (Table 5). An additional income of 9.92 Ethiopian Birr per unit Birr invested was obtained from 125 NPS and 35 N kg ha $^{-1}$ rate on the test crop Barley (HB-1307) variety compared to the other treatments. This analysis indicated that 125 NPS rate and 35 N kg ha $^{-1}$ rate on (HB -1307) variety gave (3623.4 kg ha $^{-1}$) yield with the net benefit (39849.01birr ha $^{-1}$) and the highest marginal rate of return (992.16%) are economically feasible alternative to the other treatments (Table 5). Therefore it is advisable to use 125 NPS and 35 N kg ha $^{-1}$ rates on HB -1307 variety since economically feasible to the farmers.

Table 5. *Results of partial budget analysis for NPS and Nitrogen fertilizer rates on barley (HB -1307).*

Trt ms	NPSkg /ha	N Kg/ha	Field yield	adj. yield	GB	TVC	NB	Dominance	MC	MB	MRR
1	75	17	3176	2858.4	34300.8	2061.337	32239.46		0	0	0
2	75	23	2967	2670.3	32043.6	2237.946	29805.65	D			
5	87.5	17	3410	3069	36828	2350.929	34477.07		289.59	2237.61	772.67
7	87.5	29	3484	3135.6	37627.2	2674.712	34952.49		323.78	475.42	146.83
10	100	23	3561	3204.9	38458.8	2758.261	35700.54		83.55	748.05	895.34
12	100	35	3716	3344.4	39132.8	3111.478	36021.32		353.22	320.78	90.82
15	112.5	29	3322	2989.8	35877.6	3195.028	32682.57	D			
18	125	23	3381	3042.9	36514.8	3278.576	33236.22	D			
16	112.5	35	3681	3312.9	39754.8	3290.635	36464.16		179.16	442.84	247.18
19	125	29	3412	3070.8	36849.6	3455.185	33394.42	D			
20	125	35	4026	3623.4	43480.8	3631.794	39849.01		341.16	3384.84	992.16

GB= gross benefit, TVC= total variable cost, NB= net benefit, D=dominance, MC= marginal cost, MB= marginal benefit and MRR= marginal rate of return

5. Conclusion

Inappropriate crop management practices are among key elements contributed to low productivity of Barley. To overcome such problems particularly nutrient management, application of balanced fertilizers according to the nutrient demand of crops is the basis to produce more crop output from existing land under cultivation. Among different NPS and N rates tested, the combination of 125 NPS and 35 N rates resulted the highest yield and led to highest net benefit. Based on this experiment, the economic analysis showed that 125 NPS and 35 N kg ha $^{-1}$ rates tested at Gedo and Shambu locations gave the highest Barley yield (3631.79 kg ha $^{-1}$) with the net benefit (39849.01 birr ha $^{-1}$) with the highest marginal rate of return (992.16%) are economically feasible alternative to the other treatments. Therefore it is advisable to use 125 NPS and 35 N kg ha $^{-1}$ rates on Barley (HB -1307) variety since economically feasible to the farmers. However, to reach at conclusive idea there is future line of work to get the peak point at which this fertilizer combination showed turning point.

Appendix

Table 6. *Mean squares of ANOVA for Days to Heading, Days to maturity, Plant height, Panicle length, Number of effective tiller, grain per spike, Grain yield, Above ground biomass and Harvest index of Barley in response to the rates of NPS and Nitrogen at at Gedo and Shambu.*

sources of variation	Mean squres										
	Df	DH	DM	PH	NET	PL	GPS	TSW	GY	AGBM	HI
Rep	2	21.2	23.15	17.14	1.2512	34.06	27.13	48.21ns	584656	1880317	83.69
NPS	4	8.11ns	4.74ns	14.74ns	0.6393ns	0.88ns	37.89ns	9.36ns	811889**	3676568*	35.77ns
N	3	7.94ns	12.08*	99.31**	2.1526*	18.65*	39.97ns	6.01ns	1818451**	11735773**	15.65ns
NPS*N	12	4.54ns	1.38ns	23.04ns	2.1748**	3.36ns	18.93ns	4.59ns	504977**	2162121*	21.74ns
NPS*N*Loc	12	9.98*	1.45ns	47.08**	1.8238**	4.03ns	7.17ns	9.50ns	604938**	3516557**	33.08ns
MSE	158	5.02	4.22	19.68	0.6759	6.94	28.50	6.94	192268	1100865	28.62
CV (%)		3.6	1.5	4.8	16.3	13.7	9.5	6.1	13.1	13.9	12.2

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