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Nutrient Uptake and Use Efficiency of Food Barley (*Hordeum vulgare L.*) as Influenced by NPS and NPSB Blended Fertilizers

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ABSTRACT
The experiment consisted of 12 treatments viz. control, recommended Nitrogen and Phosphorous, 50 NPS, 100 NPS, 150 NPS, 200 NPS, 250 NPS, 50 NPSB, 100 NPSB, 150 NPSB, 200 NPSB, and 250 NPSB kg ha^{-1} blended fertilizers; and was laid out in RCB design with three replications. The result indicates that the average maximum grain (1.65%) and Straw (0.72%) nitrogen concentration in 250 kg ha^{-1} NPS fertilizer treatment was significantly more than those in the other treatments followed by 250 kg ha^{-1} NPSB blended fertilizer. Similarly, maximum phosphorous concentration in grain (0.3%) and Straw (0.1%) also obtained from 250 NPS kg ha-^{1} fertilizer treatment. Maximum Sulfur concentration in grain (0.27%) and Straw (0.36%) was obtained from 200 kg ha^{-1} NPS fertilizer treatment. Thus, an average maximum agronomic efficiency of 42.7 kg kg^{-1}, apparent nutrient recovery 167.3% and physiological efficiency 106.2 kg kg^{-1}, were obtained from the application of 100 NPSB, 150 NPSB and 50 NPS kg ha^{-1} blended fertilizers respectively. In general, the extensive N, P and S uptake in grain and straw, heavier grains, higher biological yield and consequently maximized grain yield by increasing the levels of fertilizer on food barely.
Keywords: Barely, nitrogen, phosphorous and sulfur uptake and NUE indices

INTRODUCTION

Barley (*Hordeum vulgare L.*) is one of the world's main cereals, ranking fourth in production after wheat, maize, and rice (FAO, 2014). In Ethiopia barley is a most staple food and economically important widely used cereal crop next to tef (*Eragrostis tef*), maize, sorghum, and wheat (CSA, 2014) but the crop productivity was below the from expected yield, because of, several abiotic and biotic factors. The potential production areas were characterized by heavy rainfall and highly weathered acid soil due to the removal of an ample amount of exchangeable heavy cations through leaching, crop mining, and runoff which leads to soil nutrient decline and fertility of the soil. When soil nutrient availability is low, traits associated with acquisition and uptake of nutrients tend to be important, while at high levels of fertility, when nutrient availability is less limiting to yield, traits related to the utilization of the nutrient may become relatively more important (Ortiz-Monasterio *et al.* 1997).

There are different mechanisms to improve the fertilizer use efficiency increasing the crop yield, cropping system, appropriate of use fertilizer, application rate, and time and soil and water management, which are among the main management options (Fageria, 2009). Fertilizer use efficiency should be improved through the application of a balanced and appropriate fertilizer mix, which could increase crop yield, improve the physical, chemical and biological condition of the soil, and increase the revenue from fertilizer application.

Fertilization with sulfur enhances the effect of N and intervenes in soil processes that improve N-use efficiency by the crop and increase N uptake and improve overall yields by mitigating hidden soil S deficiency (Marschner, 1995 and Scherer, 2001). This improvement has been shown to be due to greater N recovery, without changes in internal efficiency (Salvagiotti and Miralles 2008; Salvagiotti *et al.* 2009). Salvagiotti and Miralles (2008) reported that sulfur addition increased biomass and grain yield in wheat, and likewise, a positive interaction between N and S, which was reflected in a greater

NUE. Since, sulfur is an essential constituent of enzymes involved in N metabolism, i.e. nitrate reductase and nitrite reductase and a sulfur deficiency could lead to a decrease in N assimilation. (Swamy *et al.,* 2005).

Uptake of N appears to be strongly affected by the application of P fertilizer, especially in soils with low P-Olsen values (Smaling *et al.,* 1993). At low P-availability, only a fraction of the potentially available N is taken up by the crop (Smaling, 1993). In soils characterized by low available N, uptake of P was stimulated by application N fertilizer through decreasing rhizosphere pH and increasing solubility of soil phosphates, stimulating root growth and root physiological capacity.

Ethiopia had subsistence agriculture has suffered for years due to a lack of proper knowledge to combat nutrient depletion. This is because of the trend of fertilizer usage has been focused mainly on the use and application of Diammonium phosphate (DAP) and Urea (supplying nitrogen and phosphorus) and absence of site-specific recommendations which is creating nutrient imbalances in soils and cause low fertilizer efficiency (Abegaz *et al.*, 2006).

Considering the fact that soil fertility is one of the biggest challenges, an obvious strategy is to increase fertilizer and nutrient use efficiency application and good agronomic practices can enhance productivity. Moreover, Balanced nutrition of crops is not only important in its own right, but maintaining an adequate level of crop nutrition is also important to help plants cope with biotic, abiotic stress, and it has both economic and environmental considerations. Meanwhile, an imbalanced fertilizer use results in low fertilizer use efficiency leading to less economic returns and a greater threat to the environment. It is imperative that fertilizers are used in an injudicious manner based on crop demand and nutrient supply from the soil. Imbalanced application of other essential nutrients is one of the reasons for low fertilizer use efficiency. Since there is a synergistic interaction of N with P, K, S, and several micronutrients, it is imperative that fertilization practices include the application of not only NP but also other deficient nutrients. Considering the increasing societal demand for food, improvement of productivity and resource use efficiency, including nutrient use efficiency (NUE), is an essential goal for agriculture. Hence, this research was designed to establish the specificity of nutrient uptake and use efficiency of Barley under the application of NPS and blended fertilizers of food barley.

MATERIALS AND METHODS

Description of the Study Area

The experiment was performed at the farmer field of Hula, southern Ethiopia (38°30’47’’ E and 06°33’30’’N at 2689 *m.a.s.l*) during growing season 2019/2020. The experimental soil is typically with a reddish-brown color, with the textural class of clay loam, non-saline nature (FAO, 2014). Three core soil samples were taken from random positions across the field before fertilizer was applied for the analysis of the physical and chemical properties of the soil. Based on analysis result the particle size distribution of the soil was, 33, 31 and 35 % sand, silt and clay respectively, with the textural class of the soil is clay loam (Table 1). The soil pH and exchangeable acidity (EA) of the experimental site soil were 5.54 (pH: H_2O) and 0.33 mg/100g, respectively. Thus, pH was moderately acidic according to (Tekalign, 1991) which suggests the presence of a substantial quantity of exchangeable H^+ and Al^{3+} ions which is associated with acidity. Mengel and Kirkby (1996) suggest that the optimum soil pH value ranges from 4.1 to 7.4 were recommended for barley production. The content of available nutrients in the soil was TN (0.12%) and OC (2.02 %) rated moderate Tekalign (1991) (Table 1). Available P content of the experimental site soil was 8.51 mg kg^{-1} (Table 1) rated as low, and it is indicative of soil capable of significant yield responses to application of the appropriate level of the nutrient. Similarly, Olsen and Dean, (1965) stated as the P content of less than 12 P kg ha^{-1} in soil indicates a crop response to P fertilizers, between 12 and 24 kg P ha^{-1} indicates a probable response. The available S and B content of the site is 21.02 and 0.5 mg kg^{-1} respectively. The cation exchange capacity (CEC) of the soil was 21.15 cmol $(^{+})$ kg $^{-1}$, which is low to moderate according to Hazelton and Murphy (2007).

Table 1. Initial soil Physic-chemical properties of experimental soil

Particle size distribution %			Textural class	pH	TN	OC	Av. P	Av. S	B	CEC (Cmol $^{(+)}$ kg^{-1})
Sand	Silt	clay			%		mg kg^{-1}			
33	31	35	Clay loam	5.54	0.12	2.02	8.51	21.01	0.51	21.15

Experimental Set-up and Procedure

The experiment was established in a randomized complete block design (RCBD) and consisted of twelve (12) treatment levels, and objects with three replications: five NPS level (50, 100, 150, 200 and 250 kg ha^{-1}), five NPSB (50, 100, 150, 200 and 250 kg ha^{-1}) blended fertilizer levels, recommended NP (positive control) and control (without any input). The blended and phosphorus (triple super phosphate - TSP) containing fertilizers were basally applied once at planting, and to minimize losses and increase use efficiency; N fertilizer was applied in the row in two times: half at planting and the other half 40 days after planting, during the maximum growth (full tillering) stage of the crop. Based on exchangeable acidity lime ($CaCO_3$) was evenly broad casted manually and mixed thoroughly in upper soils at 0.15 m plow depth and equally applied for all treatments one month before sowing. Other recommended standard agronomic practices were applied during crop growth.

$$LR, CaCO3\ (kg/ha) = Cmol\ EA/kg\ of\ soil * 0.15 * 10^4\ [m]\ ^2 * B.D(mg/m^3)/2$$

Treatments		N	P_2O_5	K_2O	S	Z	B
		Fertilizers in nutrient level					
1	Control	-	-	-	-	-	-
2	Recommended NP	64	46	-	-	-	-
3	50 kg NPS map recommended formula A	9.5	19	-	3.5	-	-
4	100 kg NPS map recommended formula A	19	38	-	7	-	-
5	150 kg NPS map recommended formula A	28.5	57	-	10.5	-	-
6	200 kg NPS map recommended formula A	38	76	-	14	-	-
7	250 kg NPS map recommended formula A	47.5	95		17.5		
8	50 kg NPSB map recommended formula B	9.05	18.05	-	3.35	-	0.355
9	100 kg NPSB map recommended formula B	18.1	36.1	-	6.7	-	0.71
10	150 kg NPSB map recommended formula B	27.15	54.15	-	6.7	-	1.065
11	200 kg NPSB map recommended formula B	36.2	72.2	-	13.4	-	1.42
12	250 kg NPSB map recommended formula B	45.25	90.25	-	16.75	-	1.775

The nutrients level in 100 kg of NPS and/or NPSB blended fertilizer is that:
NPS (19 N - 38 P2O5 – 0.0 K2O + 7 S + 0.0 Zn + 0.0 B)
NPSB (18.1 N - 36.1 P2O5 – 0.0 K2O + 6.7 S + 0.0 Zn + 0.71 B)

Sample Analyses and Calculation of Nutrient Use Efficiency

The 15g samples of grain and straw of barley were collected at full physiological maturity and sub-sampled and the materials were washed and rinsed with deionized water to remove possible contaminants. The samples were oven-dried at 70 °C for 72 hr and then ground using a Karl Kolb-RETSCH grinder to pass through a 0.5-mm mesh for determination of total nitrogen, phosphorus and sulfur concentrations. The total nitrogen concentration of the samples was determined by the conventional Kjeldahl method distillation by H_2SO_4–H_2O_2. The concentration phosphorous in straw and grain was determined by total phosphorus concentration was determined by the vanadomolybdate yellow colorimetric method (Spectrophotometer at 410-nm wavelength) and Sulfur was determined using inductively-coupled plasma spectrometry (ICPS) (George *et al.,* 2013).

Total N, P and S uptake by straw and grain were calculated by multiplying N, P and S contents by respective straw and grain yield ha^{-1}. Total N, P, and S uptake, by whole biomass, was calculated by summing up the N, P and S uptake of grain and straw. On this basis finally, applied N, P and S nutrient recovery was computed as the difference of the values of N, P and S nutrient (kg ha^{-1}) and the plant uptake values (kg ha^{-1}), nutrient use efficiency (N, P, and S) was expressed by the indices; that are commonly used to describe nutrient use efficiency. The agronomic efficiency (AE)- kg crop yield increase per kg nutrient applied) apparent recovery efficiency (ANE%)- kg nutrient taken up per kg nutrient applied); physiological efficiency (PE)- kg yield increase per kg nutrient taken up) (Mosier *et al.* 2004).

$$AE\left(\frac{kg}{kg}\right) = \frac{\text{Grain Yield F, kg} - \text{Grain Yield C, kg}}{\textit{Quntity of Nutrient applied, kg}}$$

$$PE\left(\frac{kg}{kg}\right) = \frac{\text{Biological Yield F, kg} - \text{Biological Yield C,kg}}{\text{Nutrient uptake F, kg} - \text{Nutrient uptake C, kg}}$$

$$ANR\ (\%) = \frac{\text{Nutrient uptake F, kg} - \text{Nutrient uptake C, kg}}{\text{Quantity of N applied (kg)}} * 100$$

Statistical Analysis

All data were subjected to analysis of variance (ANOVA) using Proc Mixed procedure with SAS software version 9.4 (SAS Institute Inc. Cary NC, 2014). All significant treatment mean differences were separated using the Least Significant Difference (LSD) test at *$p \leq 0.05$ level.*

RESULT AND DISCUSSION

Nutrients Concentration in Grain and Straw

The results showed that the concentration of N, P and S in n barley grain and straw were significantly ($P \leq 0.05$) influenced by the application of NPS and blended fertilizers (Table 2). The concentration of N in the grain varied from 1.29 % to 1.68%. Whereas, the concentration of N in straw was changed in a slimmer range to 0.40% to 0.72%.

The maximum (1.68% and 0.72 %) N concentrations in grain and straw were obtained from the application of 250 kg ha^{-1} NPS blended fertilizers respectively (Table 2). However, the minimum N concentration in grain (1.29 %) and straw (0.40 %) was obtained in the control or unfertilized treatment. This is due to increasing nitrogen fertilization also increased N concentration in grain and straw. Similarly, Novoa and Loomis (1981) reported that the N concentration 1.4–1.6 % (14–16 g kg^{-1}) in mature biomass reflects the final balance, which is achieved between the grain and straw fractions. Also, Fageria (2014) was reported that adequate total nitrogen concentration in barley grain and straw ranges from 20-30 g kg^{-1}. This result also agrees with, Potarzycki (2003), who found the use of fertilizers containing sulfur affects the greater the accumulation of N in the grain. Mean-while, Gondek and Gondek (2010) stated that spring wheat fertilization with S resulted in a significant increase in N content in the straw compared with control. This is because of the interaction of these elements at the level of the many metabolic processes is reflected in the growth and development of crops, which ultimately affects the level and quality of their yield.

The result indicated that the mean maximum values of P concentration in grain and straw (0.30 and 0.10%) were obtained in the plot treated by 250 kg ha^{-1} NPS blended fertilizer respectively. While the minimum P concentration in grain (0.25 %) and a stalk (0.04 %) was obtained in the control or unfertilized (Table 2). This is due to P with S be detrimental when a limited dose of S was useful that might have prohibited P buildup in the plant and its absorption improved in soil. Similarly, the author's Wilkinson *et al.* (2000) were found that nitrogen can increase phosphorus concentration levels in plants by increasing root growth and by increasing the ability of roots to absorb and translocate phosphorus.

The data on the concentration of Sulfur in barley grain and straw resulted in significant variations when the different applications of levels of NPS and blended fertilizer (Table 2). The mean values of the result indicated that maximum S concentration in grain (0.27%) and straw (0.36%) was obtained in the plot treated by 200 kg ha^{-1} of NPS blended fertilizers respectively (Table 2). Whereas, minimum S concentration by grain (0.07 %) and straw (0.11%) were obtained from the control plot. This result is in line with (Khan *et al.*, 1992) the higher values of sulfur where a high level of sulfur was applied compared to control or where low levels were applied to maize crop. The authors in (Khan *et al.*, 1992 and Mandata *et al.*,1994) were also observed that the S concentration in plant tissue improved with higher rates of S application. Also, Khan *et al.* (1992) studied that increasing S doses improved the existing SO_4-S in soil. Likewise, Black, (1968) stated that SO_4-S in soil was amplified with afterward augmentation of S addition. Also, Howarth *et al.* (2008) conclude that N deficiency caused a slower accumulation of N and S in grain, which resulted in the lower final content of these elements.

Table 2. Nitrogen, phosphorus, and sulfur uptake concentrations in food barley

Treatments (kg ha^{-1})	Nutrient Concentration (%)					
	Grain			Straw		
	N	P	S	N	P	S
Control	1.29k	0.25l	0.07e	0.40k	0.04k	0.11j
RNP	1.49e	0.28g	0.07e	0.66e	0.07g	0.13i
50 NPS	1.34j	0.26j	0.10c	0.42j	0.05i	0.14h
100 NPS	1.41h	0.27h	0.10c	0.54h	0.07g	0.15g
150 NPS	1.49e	0.29e	0.11b	0.67d	0.08e	0.21d
200 NPS	1.50d	0.29c	0.27a	0.68c	0.08c	0.36a
250 NPS	1.68a	0.30a	0.09d	0.72a	0.10a	0.13i
50 NPSB	1.38i	0.26k	0.10c	0.53i	0.05j	0.17f
100 NPSB	1.41g	0.26i	0.10c	0.59g	0.06h	0.17f
150 NPSB	1.48f	0.28f	0.11c	0.60f	0.07f	0.24c
200 NPSB	1.53c	0.29d	0.10c	0.68c	0.08d	0.18e
250 NPSB	1.56b	0.29b	0.11b	0.70b	0.09b	0.26b
LSD @ (0.05)	0.05	0.02	0.02	0.02	0.02	0.02
CV %	0.95	0.98	0.98	0.98	0.98	0.98

Treatments with the same letter are not significantly different ($P \leq 0.05$), RNP: Recommended nitrogen and phosphorous, N: nitrogen, P: phosphorous and S: sulfur

Nutrients Uptake in Grain and Straw

The results presented in Tables 3 indicate that the application of NPS and different level of blended fertilizers had significantly influence on the uptake of N, P and S in barley grain and straw. The maximum N uptake by grain (74.7 kg ha^{-1}) and Straw (53.1 kg ha^{-1}) was obtained from the application of 200 kg ha^{-1} NPSB and 250 kg ha^{-1} NPSB blended fertilizers respectably (Table 3). While the lowest N uptake by grain (18.7 kg ha^{-1}) and straw (9.7 kg ha^{-1}) were obtained from control or unfertilized treatment. This is because of a greater N uptake was observed when N fertilizer rate was increased. Likewise, the results showed an evident N and S synergism since the addition of S boosted N uptake as N fertilizer rates increased. Also, the productivity of the crop is directly associated with the accumulation of N nutrient in the crop, the productivity of the crop i.e. treatment that accumulates maximum N nutrient gave the highest yield. The maximum yield associated with the highest dry matter production and straw N-uptake increased significantly with the optimum nutrient application.

Also, Hall, (2002) was reported that the average, 0.45 kg of nitrogen produces an increase dry matter accounting to about 5.9 kg grain and 10.9 kg straw that is approximately 33% (0.15 kg) nitrogen recovered in the crop. Similarly, Fageria *et al.* (2009) reported that adequate and blended form of fertilizer absolutely enhances the total nutrient uptake of N. This result agrees with the finding of Woubshet *et al.,* (2017) were investigate that application of 150 kg ha^{-1} NPSB blended fertilizer with compost increase the straw yield by 5.9 t ha^{-1}. This is due to the application of Sulfur fertilizer can increase N uptake, improve N use efficiency (Marschner, 1995; Scherer, 2001). Nitrogen uptake is positively related to the grain yield in crops and understanding the N uptake yield relationship and quantifying N requirements would be of great benefit for optimizing N fertilization for annual crops (Yue *et al.,* 2012).

Phosphorous uptake by grain and straw ranged from 3.6 to 14.2 kg ha^{-1} and 0.9 to 6.8 kg ha^{-1}, respectively. The highest P uptake by grain (14.2 kg ha^{-1}) and straw (6.8 kg ha^{-1}) was obtained from plots treated by 200 kg ha^{-1} NPSB and 250 kg ha^{-1} NPS blended fertilizer respectively (Table 3). However, the lowest P uptake by grain (3.6 kg ha^{-1}) and stalk of (0.9 kg ha^{-1}) was recorded from the control or unfertilized plot. Fageria *et al.* (2009) were also reported that in cereals, nutrient accumulation is associated with dry matter production and yield of grain and straw nutrient uptake increased with the optimum nutrient application. Foth, (1990) reported that grain and straw yields of barley 2150.36 and 2508 kg ha^{-1}, the uptakes of P nutrients were 7.9 and 3.4 kg ha^{-1}, respectively and an average of 0.24 % of total biomass yields contained P on a weight basis. Marschner, (1995) was reported that nutrient uptake is more important as it contains a combined application of macro- and micro-nutrients especially S in addition to NP, because S fertilization helps to enhance the uptake of N, P, in the plants. Assefa, (2008) was stated that grain yield was improved as the accumulation of nutrients improved due to the application of a higher fertilizer rate.

Sulfur uptake by grain and straw was significantly ($P \leq 0.05$) affected due to the application of the different level of blended fertilizers. The highest S uptake by grain (11.9 kg ha^{-1}) and straw (25.2 kg ha^{-1}) was obtained in the plot treated by 200 kg ha^{-1} NPS blended fertilizers respectively (Table 3). The lowest S uptake by grain (1.0 kg ha^{-1}) and straw (2.7 kg ha^{-1}) was obtained from control respectively. This result was agreed with Salvagiotti and Miralles (2008) when the supply of sulfur was insufficient, the content of total sulfur decreased to about 0.1% in straw and to 0.05-0.07% in stems. Under conditions of sulfur shortage, the intensity of its uptake by roots and transport to aerial parts were much higher than insufficiently nourished plants. Also, Salvagiotti and Miralles (2008) reported that sulfur addition increased biomass and grain yield in wheat, reporting a positive interaction between N and S, which was reflected in a greater NUE. Since, sulfur is an essential constituent of enzymes involved in N metabolism, i.e. nitrate reductase and nitrite reductase and a sulfur deficiency could lead to a decrease in N assimilation. (Swamy *et al.,* 2005). The efficiency of nutrients absorption often determined as the ability of the plants to absorb a certain element at a low level of soil stocks or the nutrient medium (Dawson *et al.,* 2008).

Table 3. Nitrogen, phosphorus and sulfur uptake by food barley

Treatments (kg ha^{-1})	Nutrient Uptake (kg ha^{-1})					
	Grain			Straw		
	N	P	S	N	P	S
Control	18.7f	3.6f	1.0h	9.7d	0.9f	2.7f
RNP	56.4b	10.5b	2.7efg	46.1a	4.5cd	8.9de
50 NPS	31.7e	6.3e	2.4fg	16.1cd	1.8ef	5.6ef
100 NPS	41.9d	8.1d	2.9ef	28.2bc	3.4d	7.9de
150 NPS	49.8bcd	9.6bcd	3.7cd	48.4a	5.6abc	15.2c
200 NPS	66.4a	12.9a	11.9a	47.0a	5.8abc	25.2a
250 NPS	73.0a	12.9a	3.9c	51.5a	6.8a	9.3d
50 NPSB	30.8e	5.8e	2.3g	22.6bc	1.9ef	7.1de
100 NPSB	45.0cd	8.42d	3.2cd	29.3b	3.1de	8.4de
150 NPSB	53.0bc	10.2bc	3.9c	43.4a	5.1bc	17.2bc
200 NPSB	74.7a	14.2a	4.9b	52.1a	6.1ab	13.9c
250 NPSB	69.4a	12.9a	4.8b	53.1a	6.5a	18.9b
LSD (0.050	9.4	1.8	0.7	12.1	1.4	3.4
CV %	10.9	11.1	10.4	19.2	19.6	17.9

Treatments with the same letter are not significantly different ($P \leq 0.05$), RNP: Recommended nitrogen and phosphorous, N: nitrogen, P: phosphorous and S: sulfur

Agronomic Efficiency

Agronomic efficiency is the amount of additional yield obtained for each additional kg of nutrient applied, (Mengel, *et al.,* 2001; Fageria and Baligar, 2001). The result revealed that the application of different levels of NPS and blended fertilizers had a significant effect on the agronomic efficiency of barley. The highest improvement of agronomic efficiency (42.7 kg kg^{-1}) was obtained from plots that received 100 NPSB kg ha^{-1} whereas, the lowest (27.1 kg kg^{-1}) agronomic efficiency was attained from 250 NPS kg ha^{-1} (Table 4). This is because at increasing levels of fertilizer agronomic efficiency was decreased. Similar to this finding, Raun and Johnson, (1999) stated that with increasing fertilizer, there was a much larger average decline in agronomic efficiency than in the recovery of fertilizer nutrients or in physiological efficiency. with this finding in line, Jones *et al.* (2011) and Malkouti, (2008) were stated matching appropriate essential macronutrients and micronutrients with crop nutrient uptake could optimize nutrient use efficiency and crop yield.

Physiological Efficiency

Physiological efficiency is the biological yield obtained per unit of nutrient uptake (Fageria and Baligar, 2001). The highest value (106.2 kg kg^{-1}) of physiological efficiency was obtained from the application of 50 Kg ha^{-1} NPS blended fertilizer. Although, the lowest value (53.2 kg kg^{-1}) was recorded in the plot treated by 200 kg ha^{-1} NPS blended fertilizer (Table 4). The result showed that yield increased per kilogram nutrient accumulated in the barley plant was increased with increasing a combination of nutrient application. Increasing fertilizer, there was a much larger average decline in agronomic efficiency than in the recovery of fertilizers or in physiological efficiency (Raun and Johnson, 1999). In another study, Fotyma (2003) stated that the effectiveness of nutrients can be evaluated using such indicators as agricultural efficiency and physiological efficiency. These indicators allow us to determine the ability of plants to process downloaded nutrients on yield. Also, according to Rutkowska (2004) both of these indicators reach the largest values in a range of small doses of fertilizer and decrease with the level of fertilization. This is similar to the presented research.

Apparent Nutrient Recovery (ANR)

Apparent nutrient Recovery efficiency is a measure of the ability of the crop to extract nutrients from the soil or is a portion of the applied nutrient that is taken up by the crop (NPS uptake in kg/NPS applied in kg) (Mosier *et al.,* 2004). The result revealed that the highest (167.3 %) apparent nutrient recovery efficiency was obtained at 150 kg ha^{-1} NPSB blended fertilizer, Whereas the lowest apparent nutrient recovery efficiency (110.0 %) was obtained at, the plot received recommended NP (Table 4). The increment of NPSB might be due to the application of combined macro with micronutrients in the appropriate form of fertilizer. Spring barley showed a relatively high value of apparent recovery efficiency (66% on average), which could be explained by the mean of nitrogen application in small, split doses well-fitted to N requirements and the rate of nitrogen and biomass accumulation (Mosier *et al.,* 2004).

Table 4. The Mean Indices of N-P-S efficiency for food barley

Treatments (kg ha^{-1})	Quantity of Nutrient (kg ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	AE	PE	ANR%
Control	0	1.45g	2.48d			
RNP	84.1	3.8bc	6.9ab	28.0	69.3	110.0
50 NPS	21.3	2.33ef	3.91cd	41.3	106.2	128.2
100 NPS	42.6	2.96de	5.26bc	35.5	70.4	131.0
150 NPS	63.9	3.33cd	7.24a	29.4	65.7	149.8
200 NPS	85.2	4.43ab	6.98a	35.0	53.8	155.7
250 NPS	106.5	4.33ab	7.16a	27.1	59.7	113.5
50 NPSB	20.3	2.2f	4.22c	37.0	62.8	167.2
100 NPSB	40.6	3.18cd	4.96c	42.7	96.2	149.9
150 NPSB	57.5	3.59cd	7.21ab	37.2	67.8	167.3
200 NPSB	81.1	4.9a	7.73a	42.5	64.5	159.4
250 NPSB	101.4	4.45ab	7.36a	29.6	58.3	127.2

Treatments with the same letter are not significantly different ($P \leq 0.05$) AE*: Agronomic efficiency, PE: Physiological nutrient use efficiency and ARE: apparent recovery efficiency*

CONCLUSION

In conclusion, it was observed that on soil with low N, P and S supply class, NPS and NPSB blended fertilization increased grain yield of food barley in the rate of 200 NPSB kg ha^{-1}. Extensive N, P and S uptake in grain and straw, heavier grains, higher biological yield and consequently maximized grain yield by increasing the levels of NPS and NPSB fertilizer on food barely. Therefore, based on the finding of the current study it could be concluded that maximum N and P concentrations and uptake in grain and Straw were obtained from 250 NPS kg h^{-1}. While maximum S concentrations and uptake in grain and Straw were obtained from 200 NPS kg h^{-1}. Under the low level of NPS and NPSB fertilizer application, a tendency to increasing AE and PE of food barley was observed. In this situation, barley fertilization with 200 NPS or 200 NPSB kg ha^{-1} should be recommended in practice as the present study indicated that it guarantees the highest grain yield and the highest utilization of nutrients from fertilizers. From an environmental point of view, a higher RE is a desired feature associated with a higher capacity of the crop to capture nutrients from the soil.

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