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Effects of Nutrient Management on Growth, Agronomic Efficiency, and Economic Yield of Barley in Kandahar, Afghanistan

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ABSTRACT

Barley (*Hordeum vulgare*) is a major grain crop worldwide, including mining in Afghanistan. Indigenous nutrients are frequently the most limiting factors for crop output in the world's major agricultural areas; therefore, effective fertilizer use tactics generally result in significant financial gains for farmers. A field experiment was conducted at the research farm of the Afghanistan National Agricultural Science and Technology University (ANASTU) in Kandahar, Afghanistan. The experiment consisted of two barley varieties, viz., Takhar Barley 013 and Darulaman Barley 013, combined with six indigenous nutrient supply treatments. The set of treatment combinations was replicated three times in a factorial randomized block design. Among Indigenous nutrient supply, agronomic use efficiency (AUE) of N (12.88 kg kg-N^{-1}), P (25.75 kg kg-P^{-1}), K (40.0 kg-K2O $^{-1}$) and Zn (367.9 kg kg-Zn^{-1}), PFP of N (29.2 kg kg-N^{-1}), P (58.3 kg kg-P^{-1}), K (116.7 kg kg- K2O $^{-1}$) and Zn (833.4 kg kg-Zn^{-1}), gross returns (109085.4 AFN ha^{-1}) and net returns (50089.5 AFN ha^{-1}) were significantly higher with application of recommended rates of fertilizer application (NPKZn) as compared to omission of nutrients. Whereas N omitted plots recorded significantly, AUE omitted plots over other nutrients. Therefore, the Takhar Barley 013 genotype, along with the recommended rate of fertilizers, was found to be more productive and economically remunerative for cultivation in Kandahar, Afghanistan.

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INTRODUCTION

Barley (*Hordeum vulgare*) is a major grain crop worldwide, ranking fourth in terms of both quantity produced and area under cultivation among cereal crops. Around 55 million hectares of barley are harvested annually, yielding about 140 million tons. Afghanistan has 68179 hectares of area under barley cultivation, with a production of 94995 tons (Afghanistan

Statistical Yearbook 2016–17). Barley is more productive under adverse environments than other cereals. Barley is grown in all of Afghanistan's provinces under various agro-climatic conditions. However, due to poor nutrient management practices, barley yield in Afghanistan is quite low (1.39 t ha^{-1}).

However, the more efficient use of applied nutrients and their uptake depend greatly on nutrient-responsive genotypes (Kotwica and Jaskulski, 1999; Rashid and Khan, 2007). Although barley genotypes exhibit a superior ability to cope with mineral nutrient deficiencies, the growth and yield of barley are significantly impacted under a limited supply of NPK (Schmidt et al., 2019). Therefore, a more generic nutrient evaluation method that considers both site-specific Indigenous soil nutrient supply and nutrient interactions is needed to formulate more accurate fertilizer recommendations for different crop genotypes. Furthermore, most site-specific approaches for assessing soil fertility and nutrient requirements focus on a single nutrient, ignoring the fact that the availability of other nutrients influences nutrient uptake (Abegaz, 2008).

The application of P fertilizer, for example, appears to have a significant impact on N uptake, particularly in soils with low Olsen P values. Only a small portion of the potentially available nitrogen (N) is taken up by the crop when phosphorus (P) availability is limited (Alam et al., 2004; Rana et al., 2018). N-fertilizer treatment promoted P-uptake in soils with low available N by decreasing the rhizosphere pH and increasing the solubility of soil phosphates, thereby promoting root development and root physiological capacity (Sayed et al., 2000; Omran et al., 2018). Furthermore, as nitrogen availability improves, water use efficiency (Rajanna et al., 2017; Rajanna et al., 2018). Generally, the N:P ratio in plant tissue varies within a narrow range, so a deficiency in one element can limit the uptake of the other (Heba et al., 2021). Potassium application can significantly boost yields, especially in sites where crop residues are removed during continuous cropping. Optimal moisture, nitrogen, and phosphorus availability, on the other hand, leads to higher yield responses to K fertilizer.

In Afghanistan, the nitrogen use efficiency of barley remains low due to traditional, blanket, and unbalanced fertilizer application. To enhance barley growth and nutrient use efficiency, it is essential to assess the soil's capacity to supply key nutrients, including nitrogen (N), phosphorus (P), potassium (K), and zinc (Zn). (Rana et al., 2018; Heba et al., 2021). As a result, to maintain the balance of necessary nutrients in barley production, the uptake and elimination of biologically significant elements, such as N, P, K, and Zn, in crop yields must be examined. Furthermore, indigenous nutrients are frequently the most limiting factors for crop output in the world's major agricultural areas; therefore, good fertilizer use tactics generally result in significant financial gains for farmers. All of the nutrients listed above play a critical role in crop productivity (Oikeh et al., 2007; Worku et al., 2007; Omran et al., 2018; Rana et al., 2018; Heba et al., 2021).

Nitrogen is one of the most critical plant nutrients for agricultural productivity. Nitrogen is the most important factor in producing consistently good yields in cereals. During various stages of plant growth, supply and demand play a crucial role in determining the rate of N uptake and partition (Ali, 2011; Hameed, 2011). At tillering, stem elongation, booting, heading, and grain filling, for example, soil N supply must be high; as a result, barley requires more N for its growth, development, reproductive organs, and finally for increased yield and high protein accumulation in the kernel. As a result, nitrogen is regarded as one of the most significant variables influencing crop development (Sathyamoorthi et al., 2008; Omran et al., 2020; Heba et al., 2021). It is a component of plant proteins and chlorophyll ($C_{55}H_{72}O_5N_4Mg$), as well as nucleotides, phospholipids, enzymes, hormones, vitamins, and other molecules with significant physiological value in plant metabolism. It regulates the consumption of carbohydrates, potassium, phosphorus, and other essential elements to a significant extent.

The results, however, varied by region in terms of indigenous nutrient supply and fertilizer use efficiency. There has been no investigation on indigenous nutrient management and fertilizer use efficiency in barley in Afghanistan. Afghanistan urgently requires a nutrient supply and fertilizer use strategy that maximizes input efficiency and effectiveness. Thus, keeping the above points in view, the present investigation entitled "Effects of Nutrient Management on Growth and Agronomic Efficiency of Barley Varieties in Kandahar, Afghanistan" at the Research Farm of Afghanistan National Agricultural Science and Technology University (ANASTU), Kandahar, with the following objectives:

1. To determine the soil Indigenous N, P, K, and Zn supply and nutrient use efficiency in barley
2. To assess the changes in soil fertility status caused by different nutrient omissions

METHODS AND MATERIALS

Experimental Site

This investigation was conducted at Tarnak Farm, Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan. Geographically, the experimental field was located in Kandahar, situated in the southern part of Afghanistan. It has a low latitude, semi-arid hot climate, and falls between latitudes ranging from 30 ° 31' North and longitudes from 50 ° 50' East, located at an altitude of about 1010 meters above sea level.

Soil Characteristics

The soils of the experimental field belong to the desert under the agroecological zone. The soil had a texture of sandy loam. The initial physical and chemical characteristics of the soil in the experimental field are presented in Tables 1 and 2.

***Table 1**. Physical properties of soil of the experimental field*

Analysis parameter	Value	Method of determination	References
Sand (%)	75.3	Modified hydrometer	Bouyoucos (1962)
Silt (%)	13.6		
Clay (%)	11.2		
Textural class	Sandy Loam	USDA Triangle	
Bulk density (Mg m^{-3})	1.48	Core sampler method	Blake and Hartge (1986)
Soil temperature (°C)	18.8	Soil thermometer	-

***Table 2**. Chemical composition of the experimental soil*

Analysis parameter	Value	Method of determination	References
Soil pH (1:2.5 soil and water suspension)	7.14	Glass electrode pH meter	Piper (1950)
EC (dS m^{-1})	2.28	EC meter	Richards (1954)
Soil organic carbon (%)	0.3	Walkley and Black method	Walkley and Black (1934)
Available N (kg ha^{-1})	125.5	Alkaline permanganate method	Subbiah and Asija (1956)
Available P (kg ha^{-1})	7.8	0.5M $NaHCO_3$ extractable P	Olsen *et al.* (1954)
Available K (kg ha^{-1})	159.2	1N NH_4OAc exchangeable K	Hanway and Heidal (1952)
Available Zn (mg kg^{-1})	0.99	DTPA	Soltanpour and Schwab (1977)

Data Collection

The experiment was carried out in a factorial randomized block design (FRBD) with 2×6 of two barley genotypes (Takhar Barley 013, H1; Darul Aman Barley 013, H2) assisted as main factor A and nutrient omission plots (F0: Control; F1: Recommended dose of fertilizer (N120, P60, K30 and Zn4.2 kg ha-1; F2-N; F3-P; F4-K; F5-Zn) assisted as factor B. The total number of plots was 36, each measuring 3 × 4 m (12 m^2). The treatment combination of the experiment was assigned randomly with three replications. The distance kept between the two main plots was 50 cm, and between blocks was 150 cm.

Land Preparation, Seed Rate, and Sowing

The field was plowed, and planking was done properly after plowing with a tractor and Rotavator. The field was leveled using a laser leveler to ensure the soil was firm, friable, and evenly distributed, promoting proper seed germination. All weeds, stubbles, and crop residue were removed and cleaned from the field. The experimental layout was prepared before sowing the barley crop. The barley varieties (Darulaman 013 and Takhar 013) were sown manually in line-drilled plots using a 100 kg ha-1 seed rate with a row spacing of 20 cm × 10 cm. The seeds were sown at a depth of about 5 cm.

Application of Fertilizers (N, P, K and Zn)

The recommended fertilizer rates of 120, 60, 30, and 4.2 kg N, P2O5, K2O, and Zn per hectare were adopted in this study. Half of the nitrogen (50%) and the full amount of phosphorus, potassium, and zinc were applied as a basal dose at sowing in the form of Urea (46 % N), Single Super Phosphate (16 % P_2O_5), Potassium Sulphate (50 % K_2O) and Zinc Sulphate (33.5 % Zn) respectively. The remaining half dose of N was top-dressed after the first and second irrigation. The recommended rates of fertilizers were applied in different plots according to the treatments. In the control plot, no fertilizers were applied.

Irrigation, Harvesting, and Threshing

Irrigations were given to the field at approximately 18-day intervals. A total of six irrigations were given from sowing to harvest. The harvesting was done manually with sickles. The barley crop was harvested from a net plot area of 2.4 × 3.6 = 8.64 m^2. The harvested materials from each net plot were carried to the lab, and the number of spikes was counted regularly.

Data Analysis

The experimental data was statistically analyzed using the standard technique of analysis of variance (ANOVA) for the design factorial randomized block design (FRBD) using OPSTAT analyzing software. The F test was used to compare the significance of treatment means (Gomez and Gomez, 1984). In all growth parameters, yield characters and nutrient use efficiencies, treatment means were compared to the standard error of means. A critical difference (P = 0.05) was calculated to assess the difference between the treatment means.

FINDINGS

Relative Growth Rate (RGR)

The periodic data on the relative growth rate of barley genotypes, recorded at 30-60 days, 60-90 days, and 90 days after sowing (DAS) at harvest, are represented in Table 4.6. Among the two high-yielding varieties, Takhar Barley 013 recorded significantly higher RGR at 30–60-day period (0.19 g $g^{-1}day^{-1}$) and 60-90 days period (0.18 g $g^{-1}day^{-1}$) over another genotype. Meanwhile, at a 90-120 day period, the Darulaman Barley 013 variety recorded a higher RGR (0.06 g g-1 day-1) compared to another genotype (Table 3). Among indigenous nutrient supply plots, the relative growth rate (RGR) of barley varied substantially throughout the crop season. The application of a recommended dose of fertilizers (N, P, K, and Zn) resulted in significantly higher relative growth rate (RGR) during the 30-60 day period (0.24 g g-1 day-1) compared to other plots. Whereas, at 60-90 days period (0.23 g $g^{-1}day^{-1}$) and 90-120 days period (0.08 g $g^{-1}day^{-1}$), significantly higher RGR was obtained with control plots as compared to other nutrient applied plots. The interaction effect on RGR of barley between genotypes and nutrient omission plots was also significantly different at 30-60, 60-90, and 90 DAS at harvest. The Findings section presents the results of the data analysis, addressing the research questions that were posed. It should comprise 20-30% of the total article length. Highlight any differences between your results and those of previous studies.

***Table 3**. Effect of nutrient management options on RGR of barley genotypes*

Treatment	Relative growth rate (g $g^{-1}day^{-1}$)		
	30-60 days period	60-90 days period	90 DAS-harvest period
Genotype			
H_1: Takhar Barley 013	0.19	0.18	0.06
H_2: Darulaman Barley 013	0.18	0.18	0.06
SEm±	0.03	0.03	0.02
LSD(P=0.05)	0.08	NS	NS
Nutrient management options			
F_0: Control	0.10	0.23	0.08
F_1: Recommended dose of fertilizer (N, P, K and Zn)	0.24	0.18	0.06
F_2: F_1-N	0.17	0.18	0.08
F_3: F_1-P	0.22	0.15	0.05
F_4: F_1-K	0.22	0.17	0.05
F_5: F_1- Zn	0.21	0.18	0.05
SEm±	0.04	0.04	0.04
LSD(P=0.05)	0.13	NS	NS
Interaction			
SEm±	0.06	0.06	0.05
LSD(P=0.05)	0.18	NS	NS

Crop Growth Rate (CGR)

The numerical data on the crop growth rate (CGR) of barley genotypes, recorded at 30-60 days, 60-90 days, and 90 days after sowing (DAS) at harvest, are represented in Table 4. Among barley genotypes, Takhar Barley 013 recorded significantly higher CGRat30-60 days period (5.05 g m^{-2} day^{-1}) and 60-90 days period (7.89 g m^{-2} day^{-1}) was recorded by Takhar Barley 013. In contrast, a comparatively higher CAGR of 90 DAS-harvest (3.71 g m-2 day-1) was observed for Darulaman Barley 013 (Table 4). Among indigenous nutrient supply plots, the crop growth rate (CGR) of barley varied substantially during the crop season. The application of a recommended dose of fertilizers (N, P, K, and Zn) resulted in significantly higher CGR at the 30–60-day period (6.85 g m-2 day-1) and the 60–90-day period (9.23 g m-2 day-1) compared to other nutrient-applied plots and control plots. Whereas, at a 90–120-day period, a significantly higher CGR of 4.41 g m-2 day-1 was obtained with nitrogen-omitted plots compared to other nutrient-applied plots. The interaction effect on the CGR of barley between genotypes and nutrient omission plots varied significantly at all crop growth periods.

***Table 4**. Effect of nutrient management options on CGR (g m^{-2} day^{-1}) of barley genotypes*

Treatment	Crop growth rate (g m^{-2} day^{-1})		
	30-60 days period	60-90 days period	90 DAS-harvest period
Genotype			
H_1: Takhar Barley 013	5.05	7.89	3.67
H_2: Darulaman Barley 013	4.77	7.66	3.71
SEm±	0.007	0.010	0.012
LSD(P=0.05)	0.020	0.030	0.037
Nutrient management options			
F_0: Control	1.98	7.52	4.33
F_1: Recommended dose of fertilizer (N, P, K and Zn)	6.85	9.23	4.05
F_2: F_1-N	3.77	6.81	4.41
F_3: F_1-P	5.70	6.66	3.18
F_4: F_1-K	5.91	8.39	3.26
F_5: F_1- Zn	5.25	8.05	2.92
SEm±	0.012	0.018	0.021
LSD(P=0.05)	0.035	0.052	0.063
Interaction			
SEm±	0.017	0.025	0.030
LSD(P=0.05)	0.050	0.074	0.090

Soil Nutrient Status

The data on soil-available nutrients, such as N, P, K, and Zn, is represented in Table 5. Barley genotypes did not differ significantly in their available nutrient status in the soil. However, indigenous nutrient supply plots had a significant influence on the available N and K status in the soil. The application of the recommended dose of fertilizers, along with no application of Zn (F5), resulted in significantly higher available N (167.6 kg ha-1) in the soil compared to N omission (F2) and control plots (F0). However, it was in line with the recommended rates applied to the plot (F1), P (F3), and K (F4) omission plots (Table 5).

***Table 5**. Effect of nutrient management options on available N, P, K, and zinc in soil after harvest of barley*

Treatment	Available N [kg ha^{-1}]	Available P [kg ha^{-1}]	Available K [kg ha^{-1}]	Zinc [mg kg^{-1}]
Genotype				
H_1: Takhar Barley 013	151.9	9.22	166.0	1.014
H_2: Darulaman Barley 013	153.3	9.19	165.6	1.012
SEm±	1.88	0.08	1.00	0.005
LSD(P=0.05)	NS	NS	NS	NS
Nutrient management options				
F_0: Control	125.1	7.89	143.5	0.975
F_1: Recommended dose of fertilizer (N, P, K and Zn)	164.0	9.99	175.3	1.045
F_2: F_1-N	128.7	9.68	179.1	1.027
F_3: F_1-P	165.5	7.84	178.7	1.032

F_4: F_1-K	164.6	9.86	142.2	1.037
F_5: F_1- Zn	167.6	9.99	176.1	0.965
SEm±	3.26	0.14	1.73	0.008
LSD(P=0.05)	9.57	NS	5.06	NS
Interaction				
SEm±	4.62	0.20	2.44	0.011
LSD(P=0.05)	NS	NS	NS	NS

Whereas the available K content in soil was significantly higher under N-omitted plots (F2) compared to other plots, it was comparable to that of P- and Zn-omitted plots. However, Indigenous nutrient supply plots did not significantly influence the available P and Zn status in the soil. However, interaction effects did not differ significantly. Provide detailed explanations for each table and figure. Use APA style for in-text citations, including the author's last name and year. For direct quotations, include page numbers. When citing multiple references, list them in alphabetical order. For sources with up to five authors, list all names in the first citation, then use "et al." for subsequent mentions.

Agronomy Efficiency (AE)

The computed data on agronomic efficiency of barley genotypes is represented in Table 6. Among the two barley genotypes, Takhar Barley 013 significantly increased the AE of N by 8.74%, P by 8.75%, and K by 54.4% compared to Darulaman Barley 013 (Table 6).

Table 6*. Effect of nutrient management options ply on agronomic efficiency of barley genotypes*

Treatment	Agronomic efficiency			
	Nitrogen [kg (kg N)$^{-1}$]	Phosphorus [kg (kg P)$^{-1}$]	Potassium [kg (kg K)$^{-1}$]	Zinc [kg (kg Zn)$^{-1}$]
Genotype				
H_1: Takhar Barley 013	9.73	19.4	38.9	277.6
H_2: Darulaman Barley 013	8.88	17.7	17.7	253.3
SEm±	0.03	0.06	0.08	0.79
LSD(P=0.05)	0.08	0.17	0.23	2.36
Nutrient management options				
F_0: Control	-	-	-	-
F_1: Recommended dose of fertilizer (N, P, K and Zn)	12.9	25.8	40.0	367.9
F_2: F_1-N	-	4.75	7.42	67.9
F_3: F_1-P	10.0	-	29.8	286.5
F_4: F_1-K	11.8	23.5	-	335.3
F_5: F_1- Zn	9.47	18.9	28.5	-
SEm±	0.04	0.09	0.12	1.25
LSD(P=0.05)	0.13	0.27	0.37	3.73
Interaction				
SEm±	0.06	0.13	0.18	1.76
LSD(P=0.05)	0.18	0.38	0.52	5.27

Similarly, the Takhar Barley 013 genotype recorded significantly higher Zn AE (277.6 kg kg-1 Zn) compared to the other tested genotype. Likewise, AE was significantly influenced by indigenous nutrient supply plots. Application of recommended fertilizers (N, P, K, and Zn) resulted in significantly higher application efficiency (AE) of N (12.88 kg kg-N-1), P (25.75 kg kg-P-1), K (40.0 kg kg-K2O-1), and Zn (367.9 kg kg-Zn-1) compared to other fertilizer-applied plots. At the same time, N omitted plots recorded significantly lower AE of N (2.40 kg kg-1 N), P (4.75 kg kg-1 P), K (7.42 kg K2O-1), and Zn (67.9 kg kg-1 Zn). The interaction effect on the AE of barley between genotypes and nutrient omission plots was found to be significant. Barley genotype 'Takhar Barley 013 (H1)' recorded significantly higher AE of N, P, K, and Zn in all the nutrient omission plots as compared to 'Darulaman Barley 013 (H2) with nutrient applied plots.

Economics Aspects of Yield

The estimates of the cost of cultivation, gross returns, net returns, and net BC ratio for two high-yielding barley varieties are represented in Table 7.

Table 7. *Effect of nutrient management options on the economics of barley genotypes*

Treatment	Cost of production (AFN ha^{-1})	Gross returns (AFN ha^{-1})	Net returns (AFN ha^{-1})	Net B: C (AFN ha^{-1})
Genotype				
H_1: Takhar Barley 013	47019	93163	46144	0.98
H_2: Darulaman Barley 013	47019	89782	42763	0.91
SEm±	-	211	211	0.005
LSD(P=0.05)	-	620	620	0.014
Nutrient management options				
F_0: Control	32947	66181	33234	1.01
F_1: Recommended dose of fertilizer (N, P, K and Zn)	54055	109085	55030	1.02
F_2: F_1-N	45447	72959	27512	0.61
F_3: F_1-P	46555	99160	52605	1.13
F_4: F_1-K	50755	105549	54794	1.08
F_5: F_1- Zn	52355	95899	43544	0.83
SEm±	-	366	366	0.008
LSD(P=0.05)	-	1074	1074	0.024
Interaction				
SEm±	-	518	518	0.01
LSD(P=0.05)	-	1518	1518	0.03

Among the two high-yielding varieties, Takhar Barley 013 recorded a higher cost of production (₹47019 ha ^{1}). In contrast, gross returns (93163 AFN ha^{-1}), net returns (46144 AFN ha^{-1}), and net B: C (0.98) were significantly higher in the Takhar Barley 013 genotype as compared to the Darulaman Barley 013 genotype. Among nutrient omission plots, application of the recommended dose of fertilizers (N, P, K and Zn) recorded higher cost of production (54055 AFN ha^{-1}) and significantly higher gross returns (109085 AFN ha^{-1}) and net returns (55030 AFN ha^{-1}) as compared to other treatments whereas phosphorus (P) omission plots (F3) recorded higher net B: C (1.13) followed by potassium (K) omitted plots as compared to N and Zn omitted plots. The interaction effects differed significantly for different treatments on the economics of the high-yielding barley genotypes.

DISCUSSION

Barley genotypes and indigenous nutrient supply treatments had a substantial impact on relative growth rate (RGR) and crop growth rate (CGR) reported at 30-60, 60-90, and 90 DAS at harvest. The Takhar Barley 013 genotype had significantly higher RGR and CGR than the Darulaman Barley 013 due to higher growth attributes, including plant height, tillers, dry matter accumulation, leaf area, and leaf area index. The application of the recommended dose of fertilizer (NPK and Zn) to indigenous nutrient supply plots resulted in significantly higher relative growth rate (RGR) and cumulative growth rate (CGR) than the other treatments. The indigenous nutrient supply clearly had an additive effect on dry matter accumulation, resulting in higher RGR and CGR. The use of the prescribed fertilizer increased the availability of nutrients and biological activity in the soil, leading to enhanced barley crop growth and development. However, plots without K fertilizer had higher RGR and CGR than plots without N, P, or Zn fertilizer.

The data on soil-available nutrients, such as available N, P, K, and Zn, showed that barley genotypes did not differ significantly in their status of available nutrients in the soil. Thus, both the tested genotypes were equally extracted nutrients and retained equal amounts of nutrients in the soil. However, indigenous nutrient supply plots had a significant influence on the available N and K status in the soil. Application of the recommended dose of fertilizers, along with no application of Zn (F5), resulted in significantly higher available N (167.6 kg ha-1) in the soil compared to N omission (F2) and control plots (F0). However, it was in line with the recommended rates applied to the plot (F1), P (F3), and K (F4) omission plots. Therefore, the omission of any single nutrient of foremost importance in plants could result in lower uptake of nutrients by the barley crop, thus retaining higher nutrients in the soil, which are available to succeeding crops. These results were in line with the findings of Ramirez et al. (2014), Puniya et al. (2015), Barlog et al. (2020), Omran et al. (2020), and Heba et al. (2021). Likewise, the recommended application of fertilizers without omitting any nutrient could result in higher uptake of nutrients by the crop, thus resulting in enhanced barley yields. Therefore, the available nutrients after harvest of the barley crop were significantly lower in the plots where recommended rates of fertilizers were applied. Whereas the available K content in soil was significantly higher under N-omitted plots (F2) compared to other plots, it was comparable to that of P- and Zn-omitted plots. These results were in line with the findings of Ram and Buttar (2012) and Puniya et al. (2015). However, indigenous nutrient supply plots did not significantly influence the available P and Zn status in the soil.

The computed data on agronomic efficiency (AE) of N/P/K/Zn nutrients was influenced significantly by barley genotypes and indigenous nutrient supply practices. Among the two tested barley genotypes, Takhar Barley 013 significantly increased the AE of N by 8.74%, P by 8.75%, and K by 54.4% compared to Darulaman Barley 013. The increase in the grain yields of the barley genotype resulted in enhanced AUE. Likewise, AE was significantly influenced by indigenous nutrient supply plots. In the current study, the fertilization with the recommended dose of N, P, K, and Zn significantly increased AE compared to other nutrient-omitted plots. Barley with higher seed zinc content also produces larger roots and shoots during early growth (Rengel, 2001), resulting in higher nutrient use efficiency in barley. These results were in line with the findings of Paulicks et al. (2011), Aghdam and Samadiyam (2014), Dapkekar et al. (2018), and Barlog et al. (2020). In contrast, the omission of N plots resulted in significantly lower AE compared to the omission of other nutrients, such as Zn, P, and K plots. Therefore, the omission of N adversely affected the nutrient uptake, growth, and yield production of barley genotypes, thereby decreasing AE (Omran et al., 2018).

The cost of cultivation was lowest with Darulaman barley 013 and highest in the Takhar Barley 013 genotype, which may be due to higher expenditure incurred on seed materials. Cultivation of the Takhar Barley 013 genotype recorded significantly higher gross returns, net returns (50113.9 AFN ha-1), and net B: C as compared to the Darulaman Barley 013 genotype. Enhanced crop yield in the respective genotype could result in providing more profits to growers under nutrient-stress conditions compared to other genotypes. Among nutrient omission plots, the application of recommended rates of fertilizer resulted in a higher cost of production due to higher expenditures incurred on fertilizers. It can be inferred that the cost of cultivation was high when fertilizers were applied in balance with nutrient omission. The results of the investigation were in line with the findings of Sayed et al. (2000), Sharma et al. (2011), and Ram and Buttar (2012). Although the cost of cultivation was higher, the application of the recommended dose of fertilizers (N, P, K, and Zn) resulted in significantly higher gross returns and net returns (50089.5 AFN ha-1) compared to other plots. Thus, enhanced yields in the balance and recommended application of fertilizers increased returns. These results were similar to those found by Alam et al. (2004), Aghdam and Samadiyam (2014), and Barlog et al. (2020). In comparison, zinc (Zn) omission plots (F5) recorded higher net B: C (1.487) followed by potassium (K) omitted plots as compared to N and P omitted plots.

CONCLUSION

Among the two high-yielding varieties, Takhar Barley 013 proved to be the most efficient genotype for attaining higher yields under the nutrient stress conditions of Afghanistan, as evidenced by its agronomic efficiency (AE) of NPKZn compared to Darul Aman Barley 013. The application of balanced fertilizers containing N, P, K, and Zn, as per recommended rates, proved beneficial by enhancing agronomic efficiency and increasing the profitability of individual nutrients compared to other treatments. Among the nutrient omission plots, the plots omitting Potassium and Zinc also recorded higher barley yields and economics, hence proving that the response to the application of K and Zn in barley under Afghan conditions is significantly higher in terms of final barley yield.

AUTHORS CONTRIBUTION

Wakil Ahmad Seerat. and Mohammad Sadiq Salihi conceptualized the research, conducted the literature review, and were responsible for writing and editing the original manuscript. Abdul Qadir Latifee conducted research and provided technical guidance, critical review, and suggestions for manuscript improvement. Hamdullah Hamim assisted in literature collection, formatting, and reference management. All authors reviewed and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that is available from the corresponding author upon reasonable request. All relevant data were generated and analyzed during the current study and have not been deposited in a public repository due to institutional or regional restrictions.

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