

Effects of NPK and Zn Fertilizer Application on Growth and Yield Attributes of Barley

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ABSTRACT

Barley is a rich source of nutrients and dietary fiber, and it is more productive under adverse environments than other cereals. The field experiment consisting of two barley varieties and treatments: Fo (control), F1 (recommended dose of fertilizer N120, P60, K30, and Zn4.2 kg ha⁻¹), F2 (F1 minus nitrogen), F3 (F1 minus phosphorus), F4 (F1 minus potassium), and F5 (F1 minus zinc) was laid out in a factorial randomized block design, replicated three times. To study the effects of NPK and Zn on growth and yield attributes of two barley cultivars under semi-arid conditions of Afghanistan. Results revealed that the growth attributes (viz., plant height, number of tillers, dry matter accumulation) and yield attributes (such as number of spikes, spike length, grains spike⁻¹, grain weight, test weight, grain yield, straw yield, and biological yield) were significantly higher with the Takhar Barley-013 genotype over 'Darulaman Barley-013.' Combined effects of NPK and zinc application increased growth attributes, viz., plant height, number of tillers, and dry matter accumulation. Similarly, yield attributes, viz., number of spikes, spike length, grains per spike, grain weight, test weight, grain yield, straw yield, and biological yield, were significantly higher with the application of recommended rates of fertilizer application (N.P.K. and Zn) as compared to the omission of nutrients. Whereas, N-omitted plots recorded significantly lower growth and yield parameters than other nutrient-omitted plots. Therefore, the Takhar Barley-013 genotype along with the recommended rate of fertilizers was found more productive and economically remunerative for cultivation in Kandahar, Afghanistan.

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INTRODUCTION

Barley (*Hordeum vulgare* L.) is the major cereal in the majority of global drylands and thus vital for the livelihoods of resource-poor farmers of such harsh agro-ecologies (Rana et al. 2014). Barley has the widest ecological range of adaptation among the cereals, which are

grown throughout the temperate and tropical regions of the world. Barley is an important cereal crop, ranking just next to rice, wheat, sorghum, and maize in terms of both acreage and grain production. The major barley-growing provinces of Afghanistan are Takhar, Balkh, Faryab, Jawzjan, and Ghazni (Afghanistan Statistical Yearbook 2016–17).

More efficient use of applied nutrients and their uptake of nutrients greatly depend on the nutrient-responsive genotypes (Rashid and Khan, 2007). Although barley genotypes show a superior ability to manage with mineral nutrient deficiencies, under a limited supply of NPK, growth and yield of barley are significantly impacted (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 nutrient uptake is influenced by the availability of other nutrients (Agha et al., 2016).

Only a small portion of the potentially available nitrogen (N) is taken up by the crop when phosphorus (P) availability is limited (Rana et al., 2018; Goudar et al., 2020). Nitrogen fertilizer treatment promoted phosphorus uptake in soils with low available nitrogen by decreasing rhizosphere pH and increasing solubility of soil phosphates, thereby promoting root development and root physiological capacity (Agha et al., 2016). Furthermore, as nitrogen availability improves, water use efficiency, or the amount of dry matter produced per unit of water consumed, increases (Rajanna et al., 2017; Rajanna et al., 2018). In general, the nitrogen-to-phosphorus ratio in plant tissue changes within a small range; hence, a lack of one element can limit the uptake of the other (Heba et al., 2021). Potassium application can significantly increase yields, especially in sites where crop residues are removed during continuous cropping. Optimal moisture, nitrogen, and phosphorus availability, on the other hand, lead to higher yield responses to potassium fertilizer.

During various stages of the plant growth, supply and demand play a crucial role in determining the rate of N uptake and partition (Ali, 2011 & Hameed, 2011). At stages like tillering, stem elongation, booting, heading, and grain filling, the soil needs to have a lot of nitrogen because barley needs more of it to grow, develop its reproductive parts, and ultimately produce a higher yield and more protein in the kernels. As a result, nitrogen is regarded as one of the most significant variables influencing crop development and yield (Heba et al., 2021).

Linking crop yields to a single nutrient's supply and uptake is inaccurate, as it ignores the obvious interconnections between nutrients. However, more efficient use of applied nutrients and their uptake of nutrients greatly depend on the nutrient-responsive genotypes (Rashid and Khan, 2007). Although barley genotypes show a superior ability to cope with mineral nutrient deficiencies, under a limited supply of NPK, the growth and yield of barley are significantly impacted (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 nutrient uptake is influenced by the availability of other nutrients (Abegaz, 2008; Agha et al., 2016). The application of P fertilizer, for example, appears to have a significant impact on N uptake, especially in soils with low P-Olsen values. Only a small portion of the potentially available N is taken up by the crop when P-availability is limited (Alam et al., 2004; Rana et al., 2018; Goudar et al., 2020). N-fertilizer treatment promoted P-uptake in soils with low available N by decreasing rhizosphere pH and increasing solubility of soil phosphates, promoting root development and root physiological capacity (Agha et al., 2016; Omran et al., 2018). In general, the N and P ratio in plant tissue changes within a small range, so a lack of 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.

High pH, low organic matter, high calcium carbonate, high erosion potential, poor soil structure, and macro- and micronutrient deficiencies are among Afghanistan's major issues (Haytowitz and Pehrsson, 2018). There has been limited investigation on NPK and Zn fertilizer application on the growth and productivity of barley, especially in Afghanistan's semi-arid regions. The previous studies focused on the separate application of NPK and Zn on barley while mostly focusing on the foliar application of Zn. Thus, the combined effects and omission of the NPK and Zn fertilizer application on growth and yield attributes, especially with soil application of Zn, are not widely investigated. The country urgently needs to develop a strategy for nutrient supply and fertilizer use that optimizes input efficiency. Thus, the experiment objective is as follows:

- The experiment aims to investigate the effects of applying NPK and Zn fertilizers on the growth and yield attributes of barley.

METHODS AND MATERIALS

The field experiment was conducted in Tarnak Farm at Afghanistan National Agricultural Sciences and Technology University (ANASTU), Kandahar, Afghanistan, during the early summer season of 2021, which is located at 31° 30' N longitude, 65° 50' E latitude, and 1010 m altitude.

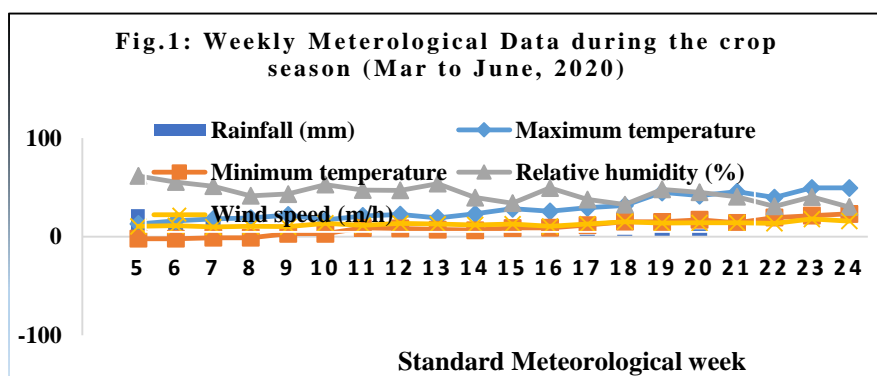


Figure 1. Weekly meteorological data during the crop season (Mar to June)

Soil Sampling and Analysis

Composite soil samples were collected from numerous spots of the field at a depth of 0–20 cm before the beginning of the experiment. The collected soil sample was air-dried, ground, and passed through a 2 mm sieve and analyzed for some important physical and chemical parameters. The soils are neutral in nature with a pH of 7.14 with an electrical conductivity of 2.28 dSm⁻¹. The soils are low in available N, phosphorus, and potassium. The initial physical and chemical characteristics of the soil of the experimental field are presented in Table 1.

Table 1. Physical and Chemical properties of the experimental field

Properties	Value	Method employed
Physical properties		
1. Sand (%)	75.3	International Hydrometer method
2. Silt (%)	13.6	Bouyoucos (1962)
3. Clay (%)	11.2	
4. Texture class	Sandy loam	USDA Triangle
5. Bulk density (Mg m ⁻³)	1.48	Core sampler method
Chemical properties		
1. Soil Organic carbon	0.3%	Walkley and Black method (1934)
2. Soil Organic matter	0.74%	Titration Method
3. Soil available Nitrogen	125.5 kg ha ⁻¹	Alkaline permanganate method Subbiah & Asija, 1956
4. Soil available phosphorus	7.8 kg ha ⁻¹	0.5M NaHCO ₃ extractable P
5. Soil available potassium	159.2 kg ha ⁻¹	Flame Photometry method
6. Available Zn (mg kg ⁻¹)	0.99	DTPA
7. Soil pH (1:2.5, Soil: water)	7.14	Glass electrode pH meter
8. EC (dS m ⁻¹)	2.28	Conductivity meter

Treatments and Experimental Design

The experiment was carried out in a factorial randomized block design (FRBD) with a 2×6 factorial of two barley genotypes (Takhar Barley-013 and Darulaman Barley-013) and nutrient omission plots (Fo: Control; F1: Recommended dose of fertilizer (N₁₂₀, P₆₀, K₃₀, and Zn_{4.2} kg ha⁻¹); F2-N; F3-P; F4-K; F5-Zn). The total number of plots was 36, each measuring 3 × 4 m (12 m²). The treatment combination of the experiment was assigned randomly with three replications.

Planting and Planting Materials

The barley varieties (Darulaman-013 and Takhar-013) were sown in lines using a manual drill in plots at a seed rate of 100 kg ha⁻¹ with a row spacing of 20×10 cm. The seeds were sown at a depth of about 5 cm. The recommended fertilizer rates of 120, 60, 30, and 4.2 kg ha⁻¹ of N,

P₂O₅, K₂O, and Zn were applied in this study. Half the amount of nitrogen (50%) and the full amount of P, K, and Zn were applied as basal dressing during sowing in the form of urea (46% N), single super phosphate (SSP) (16% P₂O₅), potassium sulfate (50% K₂O), and zinc sulfate (33.5% Zn), respectively. The remaining half dose of N was top-dressed after the first and second irrigations.

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

The recommended fertilizer rates of 120, 60, 30, and 4.2 kg of N, P₂O₅, K₂O, and Zn per hectare have been adopted in this study. Half the amount of nitrogen (50%) and the full amount of phosphorus, potassium, and zinc were applied as basal during sowing in the form of urea (46% N), single super phosphate (16% P₂O₅), potassium sulfate (50% K₂O), and zinc sulfate (33.5% Zn), respectively. The remaining half dose of N was top dressed after the first and second irrigations. The recommended rates of fertilizers were applied in different plots as per treatments. In the control plot, no fertilizers were applied.

FINDINGS

Takhar Barley-013 recorded significantly higher plant height at 30 and 90 DAS (day after sowing) and at harvest compared to Darulaman Barley-013 (Table 2). Application of the recommended dose of fertilizers (N, P, K, and Zn) recorded significantly higher plant height at 30, 60, and 90 DAS and at harvest as compared to other treatments. This pattern was followed by potassium omission plots (F₄) and (F₅) plots. The interaction effect on plant height of barley between genotypes and nutrient omission plots also varied significantly at 30 and 90 DAS and at harvest. Takhar Barley-013 (H₁) recorded significantly higher plant height in all the nutrient omission plots as compared to Darulaman Barley-013 (H₂).

Takhar Barley-013 produced a significantly higher number of tillers at 30, 60, and 90 DAS and at harvest than Darulaman Barley-013 (Table 2). Application of the recommended dose of fertilizers (N, P, K, and Zn) recorded a significantly higher number of tillers at 30, 60, and 90 DAS and at harvest over the rest of the treatments. However, potassium (K) omission plots (F₄) recorded a higher number of tillers at 30, 60, and 90 DAS and at harvest, followed by zinc (Zn) omitted plots, as compared to N and P omitted plots.

Takhar Barley-013 recorded significantly higher dry matter accumulation at 30, 60, 90 DAS and at harvest over Darulaman Barley-013 (Table 2). Dry matter accumulation was significantly highest with the application of the recommended dose of fertilizers (N, P, K and Zn) at 30, 60, 90 DAS and at harvest as compared to other nutrient management options, followed by potassium (K) omission plots (F₄), (F₃), (F₂) and the control treatment, respectively.

Table 2. Effect of NPK and Zn fertilizer application on the growth of barley

Factors	Plant height (cm)				Number of tillers (m ⁻²)				Dry matter accumulation (g m ⁻²)			
	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest	30 DAS	60 DAS	90 DAS	Harvest
Genotype												
H ₁ : Takhar Barley-013	20.7	36.2	59.0	77.2	160.0	287.2	289.0	291.3	184.6	336.2	573.0	683.2
H ₂ : Darulaman Barley-013	20.4	36.0	58.2	76.2	158.7	277.1	278.5	280.8	182.3	325.2	554.9	666.2
SE.m±	0.03	0.12	0.05	0.04	0.11	0.32	0.28	0.38	0.12	0.20	0.28	0.29
LSD (P=0.05)	0.08	NS	0.14	0.12	0.31	0.94	0.83	1.11	0.36	0.60	0.81	0.84
Treatments												
F ₀ : Control	16.8	31.5	53.1	63.0	153.9	210.6	212.6	215.4	166.9	226.2	451.8	581.7
F ₁ : Recommended dose of fertilizer (N, P, K and Zn)	24.0	41.3	66.1	87.7	165.4	345.9	347.8	349.6	195.0	400.4	677.2	798.6
F ₂ : F ₁ -N	18.2	33.2	55.0	70.0	156.3	235.8	237.1	239.1	175.2	288.2	492.5	624.8
F ₃ : F ₁ - P	18.9	34.5	55.9	74.8	158.7	290.3	291.4	293.6	187.4	358.5	558.1	653.4
F ₄ : F ₁ - K	23.3	38.6	63.8	84.0	162.4	326.1	327.9	330.1	192.2	369.4	621.3	719.0
F ₅ : F ₁ - Zn	21.9	37.7	57.9	80.6	159.6	284.1	285.9	288.5	184.0	341.6	583.0	670.7
SE.m±	0.05	0.22	0.08	0.07	0.18	0.55	0.49	0.65	0.21	0.35	0.48	0.49
LSD (P=0.05)	0.15	0.63	0.25	0.22	0.54	1.62	1.44	1.92	0.63	1.05	1.41	1.46

Yield Attributes

The results showed that the number of spikes (246.8 m⁻²), spike length (6.04 cm), number of grains per spike (39.8), grain weight (1.84 g) and test weight (32.0 g) were significantly higher with Takhar Barley-013 genotypes than with Darulaman Barley-013. Application of the recommended dose of fertilizers (N, P, K, and Zn) recorded significantly higher numbers of spikes (295.7 m⁻²), spike length (7.01 cm), number of grains per spike (42.6), grain weight (2.08 g) and test weights (35.2 g) as compared to other nutrient management options. (Table 3). Furthermore, potassium (K) omission plots (F₄) recorded a higher number of spikes (277.0 m⁻²), spike length (6.29 cm), number of grains per spike (40.9), grain weight (1.87 g) and test weights (33.0 g) followed by zinc (Zn) omitted plots as compared to N and P omitted plots. These results could be attributed to improved vegetative growth and increased metabolite transfer from source to sink, which increased barley spike grain weight.

Table 3. Effect of NPK and Zn fertilizer application on yield attributes of barley

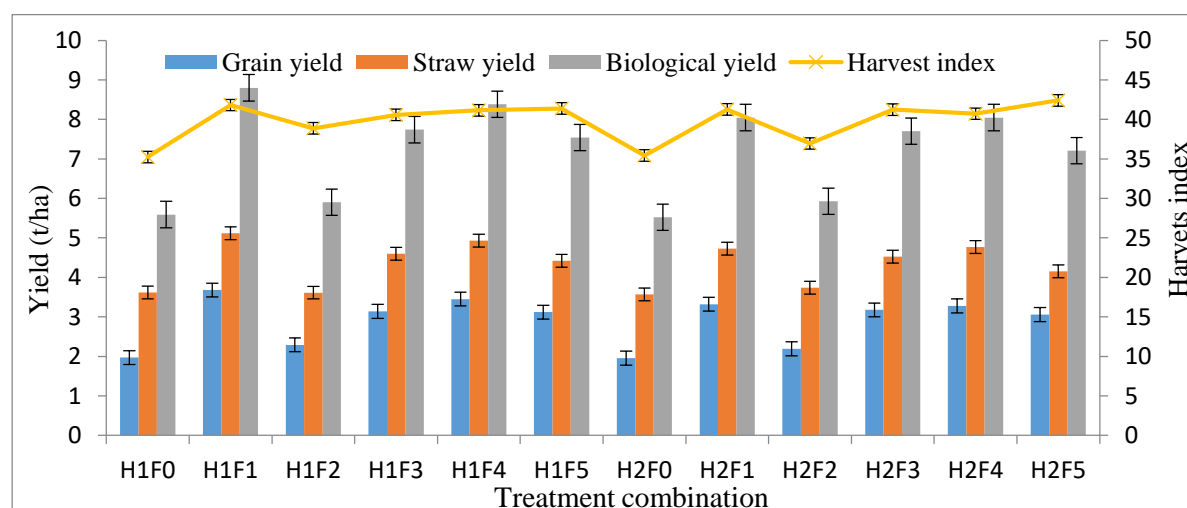
Factors	Spikes (m ⁻²)	Spike length (cm)	Grains/ spike	Grain weight (g)	Test weight (g)
<i>Genotype</i>					
H ₁ : Takhar Barley-013	246.8	6.04	39.8	1.84	32.0
H ₂ : Darulaman Barley-013	235.0	5.83	38.7	1.77	31.4
SE.m±	0.16	0.04	0.06	0.01	0.03
LSD (P=0.05)	0.47	0.11	0.19	0.02	0.09
<i>Treatments</i>					
F ₀ : Control	166.1	5.17	35.8	1.66	28.1
F ₁ : Recommended dose of fertilizer (N, P, K & Zn)	295.7	7.01	42.6	2.08	35.2
F ₂ : F ₁ -N	207.9	5.31	38.9	1.75	30.3
F ₃ : F ₁ -P	235.9	6.01	39.3	1.75	32.0
F ₄ : F ₁ -K	277.0	6.29	40.9	1.87	33.0
F ₅ : F ₁ - Zn	262.8	5.83	38.0	1.74	31.5
SE.m±	0.27	0.06	0.11	0.01	0.05
LSD (P=0.05)	0.81	0.19	0.33	0.04	0.16
<i>Interaction</i>					
SE.m±	0.39	0.09	0.16	0.20	0.08
LSD (P=0.05)	1.14	NS	0.46	0.59	0.23

Takhar Barley-013 produced significantly higher grain yield (2.94 t ha⁻¹), straw yield (4.38 t ha⁻¹), and biological yield (7.33 t ha⁻¹) than Darulaman Barley-013. However, harvest index did not differ significantly between barley genotypes. Application of the recommended dose of fertilizers (N, P, K, and Zn) resulted in the significantly highest grain yield (3.50 t ha⁻¹), straw yield (4.92 t ha⁻¹), and biological yield (8.42 t ha⁻¹) as compared to the other plots. Furthermore, potassium (K) omission plots (F₄) recorded higher grain yield (3.36 t ha⁻¹), straw yield (4.85 t ha⁻¹), and biological yield (8.22 t ha⁻¹) of barley, followed by zinc (Zn) omitted plots, as compared to N and P omitted plots. In contrast, zinc-omitted plots recorded a significantly higher harvest index (41.9) over other nutrient-applied plots, but it was at par with the application of recommended fertilizer.

Table 4. Effect of NPK and Zn fertilizer application on grain, straw, biological yield and harvest index of barley

Factors	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Biological yield (t ha ⁻¹)	Harvest index
<i>Genotype</i>				
H ₁ : Takhar Barley 013	2.94	4.38	7.33	39.8
H ₂ : Darulaman Barley 013	2.83	4.25	7.08	39.7
SE.m±	0.003	0.027	0.029	0.15
LSD (P=0.05)	0.009	0.080	0.086	NS
<i>Treatments</i>				
F ₀ : Control	1.96	3.59	5.56	35.3
F ₁ : Recommended dose of fertilizer (N, P, K and Zn)	3.50	4.92	8.42	41.5
F ₂ : F ₁ -N	2.24	3.68	5.92	37.9
F ₃ : F ₁ -P	3.16	4.56	7.72	40.9
F ₄ : F ₁ -K	3.36	4.85	8.22	40.9
F ₅ : F ₁ - Zn	3.09	4.29	7.37	41.9
SE.m±	0.005	0.047	0.050	0.27
LSD(P=0.05)	0.015	0.139	0.149	0.79
<i>Interaction</i>				
SE.m±	0.007	0.067	0.071	0.38
LSD (P=0.05)	0.022	0.197	0.211	NS

The combination of genotypes and nutrient management practices did not differ significantly on the harvest index of barley. However, Takhar Barley-013 (H₁) recorded significantly higher grain yield, straw yield, and biological yield in all the nutrient omission plots as compared to 'Darulaman Barley-013 (H₂) with nutrient applied plots' (Figure 2).

**Figure 2.** Interaction effect of NPK and Zn fertilizer application and genotypes on grain, straw and biological yield, and harvest index of barley

DISCUSSION

NPK and Zn application in a balanced manner may improve nutrient availability and biological activity in the soil, indicating their potential involvement in altering the soil and plant environment to promote the development of both morphological and biochemical components in the plant system (Aghdam and Samadiyam, 2014; Rana et al., 2018). Application of N may increase the chlorophyll content, and the resulting enhancement in photosynthesis results in greater plant height. This could also be due to increased nitrogen supply, which increased photosynthesis and improved assimilate translocation by plants (Kumar et al., 2020).

Potassium treatment resulted in a slight boost in growth parameters under the conditions in Afghanistan. In comparison to the K fertilizers, omitting N and P fertilizers could result in significant production reductions, particularly in terms of overall yield and quality of the crops grown in Afghanistan. These findings are in conformity with those of previous studies (Sharma et al., 2011; Alazmani, 2014; Tigre et al., 2014). Because N is a component of plant proteins, nucleic acids, and chlorophyll, its impact on plant height and other growth factors was more evident (Rashid and Khan, 2007; Abegaz, 2008). Phosphorus is used subsequently for vegetative and reproductive growth, and the extensive root system promotes nutrient uptake. Srivastava et al. (2015) and Rana et al. (2018) found that potassium fertilization improves glucose metabolism, enzyme activation, and osmotic regulation in the plant system.

However, the absence of N and P reduced yield attributes due to decreased growth parameters. These findings are similar to those of (Alam et al., 2004; Alazmani, 2014; Agha et al., 2016). Due to balanced fertilizer application in barley, Rashid and Khan (2007), Hameed (2011), and Srivastava et al. (2015) observed considerably higher growth and yield characteristics.

It is demonstrated that the supply of balanced nutrients is required for the plant growth and development of reproductive structures, resulting in better productivity in barley. This significant increase in grain, straw, and biological yield may be due to the higher yield attributing parameters such as number of spikes, spike length, grains per spike, grain weight, and test weight with the recommended fertilizer doses. This result is consistent with the role of nitrogen fertilizer in increasing plant vegetative growth, as well as the fact that nitrogen promotes tillering through its effect on cytokine or protein production. These results are in conformity with the findings of Ali. (2011). Potassium (K)-omitting plots (F₄) produced higher grain, straw, and biological yield of barley. The results revealed that omitting potassium and zinc had no effect on barley growth and yield. Kumar et al. (2020) and Arora and Singh (2004) found that omitting zinc fertilizers resulted in greater or similar barley yields.

CONCLUSION

Application of the recommended dose of fertilizer (N, P, K, and Zn) increased growth and yield attributes of barley. Potassium- and zinc-omitted plots also recorded higher barley yield; hence, the response to application of K and Zn in barley under Afghanistan conditions is much higher on barley yield. Omission of nitrogen and phosphorus decreased yield in barley, and hence, under Afghanistan conditions, nitrogen and phosphorus application gains foremost importance in attaining higher barley yields. Among the two high-yielding varieties, Takhar Barley-013 demonstrated better growth and yield compared to Darulaman Barley 013 in the climate conditions of the study area. Nitrogen and phosphorus were the most limiting factors in barley production in Kandahar soil conditions. Thus, it is recommended for farmers to use the recommended rate of fertilizer (N.P.K-Zn) and the Takhar Barley-013 variety in Kandahar in order to increase the productivity of barley. It is also recommended that future studies investigate the combined effects of other micronutrients with NPK barley production in local areas.

AUTHORS CONTRIBUTION

Wakil Ahmad Seerat, Mohibullah Hamdard, and Mohammad Sadiq Salihi. conceptualized the research, conducted the literature review, and were responsible for writing and editing the original manuscript. Abdul Qadir Latiffee conducted research and provided technical guidance, critical review, and suggestions for manuscript improvement. Karamatullah Fazil. and Hamdullah Hamim. assisted in literature collection, formatting, and reference management.

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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.

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