Effect of biofortification with zinc and iron on growth parameters, yield attributes and yield of Barley (*Hordeum vulgare* L.)

Abstract

A field experiment was conducted during *Rabi* season of 2021-2022 at Students' Instructional Farm (S.I.F.) of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. The present experiment having 16 treatmentcombinations replicated thrice in factorial randomized block design. Barley variety Prakhar (K 1055) (K508/NDB1081) was grown with recommended agronomic practices. On the basis of the results emanated from present investigation, it could be concluded that application of 100% RDF + soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} + two foliar application of Fe (0.5%)significantly recorded maximum growth parameters such asplant height (102.00 cm) and number of effective tillers (302.00 m^{-2}) and maximum yield attributing characters such as ear length (8.9 cm), number of grains $spike^{-1}$(50.75) and test weight (42.497 g).The result showed highest grain yield (59.55 q ha^{-1}),straw yield (69.673 q ha^{-1}), biological yield (129.22 q ha^{-1}) and harvest index (46.08 %) with 100% RDF + soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} + two foliar application of Fe (0.5%) in comparison to all the treatments during 2021-2022.

Comment [R1]: Insert the objective of the study.

Keywords: Barley, Iron, Yield andZinc.

1.Introduction

Barley(*Hordeum vulgare* L.) is one of the most important cereal crop of all over the world as well as in India. It belongs to the family of *Gramineae* (Poaceae) having chromosome number (2n=14). It is one of the most ancient cereal crop. It is paramount cereal crops and due to its adaptability and hardiness, it is regarded as the first cereal crop domesticated for use by humans as food and feed. Barley is known by its vernacular name "Jau" in India

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Barley is known for its nutritive value and rich source of proteins and vitamins groups,thus playing crucial role in food security.Barley is ecologically adaptable on a broad scale, it is primarily a crop that thrives in cool climates. It requires cool weather during early growth and warm and dry weather at maturity. Barley can sustain better under unfavourable weather conditions compared to other cereal crops **(Vangool and Vernon, 2006).**Barley can be grown on variety of soils ranging from light sandy to heavy clay soils. It performs well on properly drained loamy soils having a pH range of 7-8. Fertile deep loam and well-drained soil is ideal for barley. Barley is considered as a poor's man crop because of its low input requirements and better adaptability to extremities like salinity, drought, alkalinity and marginal lands **(FAO, 2002).**

Micronutrient deficiencies, particularly in zinc and iron, are a result of exploitative agriculture practices involving contemporary production technology, the introduction of high yielding sweet corn, and the use of high analysis fertilisers. In the future, it might become a worrying condition in the heavily farmed areas. A little more than half of the world's population has micronutrient malnutrition, which primarily results from low dietary intake of micronutrients in diets with a limited variety of foods. According to recent reports, deficiencies in Zn and Fe cause the deaths of over 5,000 children under the age of five every year. Iron and zinc are essential minerals for humans. Deficiencies in both contribute to severe cases of malnutrition.

Among micronutrients, Zincdeficiency is occurring in both crops and humans **(Hotz and Brown, 2004).** Zn deficiency in humans is currently recognized as a leading global risk factor for health and cause of mortality.Zinc solubility in soil is less, resulting in its low concentration in plants and has become the major problem across the countries **(Alloway 2009).** Zinc plays fundamental role in various metabolic processes. It is essential for several biochemical processes in the plant such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation and membrane integrity.

Iron is also playing a vital role in human health. It is essential nutrient because it is a central part of hemoglobin, which carries oxygen in the blood. It acts as a co-factor for several enzymes performing basic functions in human body. In plants, Fe helps in the formation of chlorophyll. **Ramana *et al*., (2006)** reported that most of the photosynthetic pathways depend on enzymes and coenzymes which are synthesized by micronutrients. Zn and Fe are essential for several enzymes that regulate metabolic activities in plants.Amongst the different methods; the foliar spray of micronutrients is efficient for enhancement of crop productivity.The practice of intentionally increasing the concentration of key micronutrients, such as vitamins and minerals (including trace elements), in a food to improve the nutritional quality of the food supply and give a public health benefit with low risk to health is known as fortification. Plant breeding, agronomic practices, and contemporary biotechnology techniques are all used to improve the

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nutritional value of food crops in the process of biofortification.Agronomic fortification, a quick and easy solution to the issue, is the enhancement of a specific nutrient by addition of fertilizer soil or to foliage in the proper form, timing, and growth stages of the crop. **Narwal *et al.*, (2010)** reported that maximum increase in grain yield was achieved when the recommended dose of $ZnSO_4$, at 25 kg ha^{-1} was applied as soil application and 0.5% foliar spray of $ZnSO_4$.**Yadav and Chhipa (2007**) reported that application of 50% GR iron pyrite showed significant improvement in both grain and straw yield of wheat, registering and increase of 16.7 per cent over control.Keeping in view the significance of zinc and iron on productivity parameters of barley present investigation was undertaken at the C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh.

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1. Make quotes more current
2. Insert the purpose of the study at the end of the introduction

2. Materials and Methods

2.1 Experimental Site: The field experiment was carried out during the *Rabi* season of 2021–2022 at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur on field no. 29, Students' Instructional Farm (SIF). The experimental field had a regular topography, good drainage, and a tube well that provided a reliable source of water. The farm is located in central U.P., India, on the alluvial belt of the gangetic plain.

2.2 Geographical Location

District Kanpur Nagar is situated in the Indo-Gangetic plains of central Uttar Pradesh at an altitude of 125.9 m above sea level. It is in the subtropical and semi-arid zone between the parallels of 25°26' and 26°58' north latitude and 79°31' and 80°34' east longitude.

2.3 Edaphic Condition

The soil was moist, well drained with uniform plane topography. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 8.10 (1:2.5 soil: water suspension method given by **Jackson, 1973**), electrical conductivity 0.27 dSm^{-1} (1:2.5 soil: water suspension method given by **Jackson, 1973**),low in organic carbon percentage in soil is 0.390 per cent (Walkley and Black's rapid titration method given by **Walkley and Black, 1934**),lowin available nitrogen 175.497 kg ha^{-1} (Alkaline permanganate method given by **Subbiah and Asija, 1956**),medium in available phosphorus as sodium bicarbonate-extractable P was 12.78 kg ha^{-1} (Olsen's calorimetrically method**, Olsen *et al.*, 1954**), medium in available

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potassium was 147.200 kg ha^{-1} (Flame photometer method given by **Hanwey and Heidel, 1952**), low in available zinc was0.527 ppm**(**DTPA extraction method given by (**Lindsay and Norvell, 1978)** and low inavailable iron was3.900 ppm**(**DTPA extraction method given by (**Lindsay and Norvell, 1978).**

2.4 Experimental Details

The experiment was laid out in Factorial randomized block design and replicated thrice. Here are four methods of Zn i.e. Zn_0 (No Zn), Zn_1 (one spraying @ 0.5% $ZnSO_4$), Zn_2 (two spraying @ 0.5% $ZnSO_4$), Zn_3 (soil application @ 25 kg $ZnSO_4$ ha^{-1}) and four methods of Fe i.e. Fe_0 (No Fe), Fe_1 (one spraying @ 0.5% $FeSO_4$), Fe_2 (two spraying @ 0.5% $FeSO_4$), Fe_3 (soil application @ 10 kg $FeSO_4$ ha^{-1}) comprising with 16 treatment combinations.

Tableno.-1: Treatment details

S.No.	Treatments	Treatment Combinations
1	T_1	(Zn_0 Fe_0) Control
2	T_2	(Zn_0 Fe_1) No Zn + Fe (one foliar spraying)
3	T_3	(Zn_0 Fe_2) No Zn + Fe (two foliar spraying)
4	T_4	(Zn_0 Fe_3) No Zn + Fe (soil application)
5	T_5	(Zn_1 Fe_0) Zn(one foliar spraying) + No Fe
6	T_6	(Zn_1 Fe_1) Zn (one foliar spraying) + Fe (one foliar spraying)
7	T_7	(Zn_1 Fe_2) Zn (one foliar spraying) + Fe (two foliar spraying)
8	T_8	(Zn_1 Fe_3) Zn (one foliar spraying) + Fe (soil application)
9	5	(Zn_2 Fe_0) Zn (two foliar spraying) + No Fe
10	T_{10}	(Zn_2 Fe_1) Zn (two foliar spraying) + Fe (one foliar spraying)
11	T_{11}	(Zn_2 Fe_2) Zn (two foliar spraying) + Fe (two foliar spraying)
12	T_{12}	(Zn_2 Fe_3) Zn (two foliar spraying) + Fe (soil application)
13	T_{13}	(Zn_3 Fe_0) Zn (soil application) + No Fe
14	T_{14}	(Zn_3 Fe_1) Zn (soil application) + Fe (one foliar spraying)
15	T_{15}	(Zn_3 Fe_2) Zn (soil application) + Fe (two foliar spraying)
16	T_{16}	(Zn_3 Fe_3) Zn (soil application) + Fe (soil application)

* Recommended dose of NPK @ 60:30:20 kg $ha^{-1}$was applied uniformly to each treatment.

Comment [R8]: 1.**Table 1: Treatment details**
2.Redraw all tablesaccording toAuthorGuidelines.
3.Cite Table 1 in thetext

2.5.2 Fertilizer application: All plots received a basal dressing of 30 kg of nitrogen, 30 kg of phosphorous, and 20 kg of potassium, respectively, by the use of urea, diammonium phosphate, and muriate of potash. The remaining half of the nitrogen dose was delivered to the standing crop during the initial irrigation. Zinc and iron were applied by soil application and spraying as per treatment through Zinc sulphate andferrous sulphate respectively.

2.5.3 Seed and sowing: A seed rate of 100 kg per hectare of barley variety Prakhar (K 1055) (K508/NDB1081) was used and sowed on 04 December 2021. Row to row distance was 22.5 cm. Seeds were sown at a depth of about 3 to 5 cm.

2.5.6 Harvesting: When the plants turned yellow and dried up, on April 10, 2022, the crop was harvested. After measuring the weight of the air-dried bundles with a spring balance, the harvested crop was tied in labelled bundles and threshed using a tractor-drawn thresher. Plot-by-plot records of the grain and straw yields were made and translated to q/ha**.**

2.6 Observations recorded

2.6.1 Biological yield (q ha^{-1}): The bundle weight of each plot was recorded three days after harvest with the help of electronic balance and was converted into q/ha to express biological yield.

2.6.2 Grain yield (q ha^{-1}): The total weight of clean and dried grains from each plot was weighed with the help of electronic balance in kg/ha and converted into q/ha.

2.6.3 Straw yield (q ha^{-1}): Straw yield of each plot can be obtained by deducting the grain yield from the respective biological yield and expressed in q/ha.

2.6.4 Harvest index (%): The ratio of economic yield (grain yield) to the biological yield (grain and stover yield) was worked out as harvest index with the help of following formula as suggested by **Singh and Stoskopf (1971).**

Harvest index (%) = Economical yield (q ha^{-1})/ Biological yield (q ha^{-1}) x 100

2.7 Statistical Analysis: The data on various characters studied during the course of investigation were statistically analyzed for factorial randomized block design. Wherever treatment differences were significant ("F" test), critical differences were worked out at five per cent probability level. The data obtained during the study were analyzed statistically using the methods advocated by **Gomez and Gomez (1984).**

3. Result and Discussion

Comment [R9]: Review all citations in the Result and Discussion.

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3.1. Growth Parameters

Data pertaining to growth parameters mainly no.of plants m^{-2}, no. of effective tillers m^2, plant height (cm), are presented in table no. 2 clearly revealed that application of Zn and Fe in different modes increased these attributes significantly over control. Soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} showedits superiority on increase in growth parameters over two foliar application of Zn (0.5%) and one foliar application of Zn (0.5%). Maximum no.of plants101.248 per m^2, no. of effective tillers295.750 m^{-2}, plant height 99.50cm was recorded with soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1}which was 10.95%, 7.83 % and 4.18 % higher than the yield of its respective controlwhile two foliar application of Fe (0.5%) showedmaximum increase in growth parameters over soil application of Fe @ 10 kg $FeSO_4$ ha^{-1} and one foliar application of Fe (0.5%). Maximum no.of plants 99.373 per m^{-2}, no. of effective tillers 290.251 m^2, plant height 98.999 cm was recorded with two foliar application of Fe (0.5%) which was 8.16%, 3.66 % and 3.66 % higher than the yield of its respective control. Likewise, Zn and Fe applicationin different modes their interaction also influenced the growth parameters but the increase in growth parameters was found non-significant except in the case of plant population (m^{-2}). Maximum increase in growth parameters was recorded with soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} and two foliar application of Fe (0.5%). **Gill and Singh (2009)** stated that the foliar use of micronutrients particularly Fe proved highly economical than their soil application. The increase in growth parameters of barley might be due to increased cell expansion and various metabolic process in the presence of adequate available nutrients. These findings are further supported by **Ramana *et al.*,(2006).**The increase in growth parameters due to Zn application has also been reported by **Ghatak*et al.* (2005),Kenbaev and Sade (2002),Arora and Singh (2004),Kerum*et al.*,(2012), Boonchuay*et al.*, (2013).**The increase in growth parameters due to application of Fe in different modes has been reported by **Kulandaivel*et al.*,*(2004)***. These findings are further supported by **Sarangi *et al.*, (2006).**

Table no.-2: Effect of Zinc and Iron on growth parameters of barley

Level of Zn	Levels of Fe				Mean
	Fe_0	Fe_1	Fe_2	Fe_3	
	Plant population (m^{-2})				
Zn_0	87.50	90.01	94.99	92.50	**91.25**
Zn_1	89.99	92.50	97.50	95.00	**93.74**
Zn_2	92.50	95.00	100.00	97.50	**96.25**
Zn_3	97.49	99.99	105.00	102.50	**101.24**
Mean	**91.87**	**94.37**	**99.37**	**96.87**	
No. of effective tillers (m^{-2})					
Zn_0	268.000	274.000	279.000	275.997	**274.249**
Zn_1	278.000	282.000	288.003	284.000	**283.001**
Zn_2	284.000	288.003	292.000	290.003	**288.502**
Zn_3	290.000	294.000	302.000	297.000	**295.750**
Mean	**280.000**	**284.501**	**290.251**	**286.750**	
Plant height (cm)					
Zn_0	94.003	95.000	97.000	96.000	**95.501**
Zn_1	95.000	96.000	97.997	97.000	**96.499**
Zn_2	96.003	96.997	99.000	97.997	**97.499**
Zn_3	97.000	98.000	102.000	101.000	**99.500**
Mean	**95.502**	**96.499**	**98.999**	**97.999**	
		Zn	**Fe**	**Zn x Fe**	
Plant population (m^{-2})	S.E(m)±	0.519	0.519	1.038	
	CD(p=0.05)	1.506	1.506	3.011	
No. of effective tillers (m^{-2})	S.E(m)±	1.705	1.705	3.41	
	CD(p=0.05)	4.949	4.949	NS	
Plant height (cm)	S.E(m)±	0.471	0.471	0.942	
	CD(p=0.05)	1.367	1.367	NS	

Comment [R10]: Table 2: Effect of Zinc and Iron on growth parameters of barley.
1. Redraw all tablesaccording toAuthorGuidelines.
2. Cite Table 1 in thetext

3.2. Yield Components

Data pertaining to yield attributing parameters mainly ear length (cm), no. of grains spikes^{-1} and test weight (1000 grains) are presented in tableno. 3clearly revealed that application of Zn and Fe in different modes increased these attributes significantly over control. Soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} showed its superiority on increase in yield attributing parameters over two foliar application of Zn (0.5%) and one foliar application of Zn (0.5%). Soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} showed its superiority on increase in growth parameters over two foliar

Comment [R11]: table 3

application of Zn (0.5%) and one foliar application of Zn (0.5%). Maximum ear length 8.625 cm, no. of grains spikes^{-1} 51.502 , test weight 41.312 g was recorded with soil application of Zn @ 25 kg $ZnSO_4$ha^{-1}while two foliar application of Fe (0.5%) showed maximum increase in growth parameters over soil application of Fe @ 10 kg $FeSO_4$ ha^{-1} and one foliar application of Fe (0.5%). Maximum ear length 7.600 cm, no. of grains spikes^{-1}50.750, test weight 41.299 g was recorded with two foliar application of Fe (0.5%). Likewise, Zn and Feapplication in different modes their interaction also influenced the yield components but the increase in yield components was found non-significant except in the case of ear length. Maximum increase in yield components was recorded with soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} and two foliar application of Fe (0.5%). These findings are further supported by **Sarangi *et al.*, (2006) and Gill and Singh (2009).**

Table no.-3: Effect of Zinc and Iron on yield attributing characters of barley

Level of Zn	Levels of Fe				Mean
	Fe_0	**Fe_1**	**Fe_2**	**Fe_3**	
	Ear length (cm)				
Zn_0	6.600	6.000	6.400	6.203	**6.301**
Zn_1	6.300	6.803	7.200	7.100	**6.851**
Zn_2	7.300	7.600	7.900	7.800	**7.650**
Zn_3	8.200	8.600	8.900	8.800	**8.625**
Mean	**7.100**	**7.251**	**7.600**	**7.476**	
Number of grains spike^{-1}					
Zn_0	40.000	43.000	47.000	45.000	**43.750**
Zn_1	44.000	47.000	49.997	48.000	**47.249**
Zn_2	47.000	49.000	52.003	50.000	**49.501**
Zn_3	49.000	51.003	54.000	52.003	**51.502**
Mean	**45.000**	**47.501**	**50.750**	**48.751**	
Test weight (g)					
Zn_0	36.200	37.800	39.600	38.700	**38.075**
Zn_1	38.750	40.150	41.200	40.850	**40.238**
Zn_2	39.700	40.400	41.900	41.200	**40.800**
Zn_3	40.200	40.750	42.497	41.800	**41.312**
Mean	**38.713**	**39.775**	**41.299**	**40.638**	
		Zn	**Fe**	**Zn x Fe**	
Ear length (cm)	S.E(m)±	0.046	0.046	0.092	
	CD(p=0.05)	0.134	0.134	0.267	
Number of grains spike^{-1}	S.E(m)±	0.239	0.239	0.479	
	CD(p=0.05)	0.695	0.695	NS	

Comment [R12]: **Table 3: Effect of Zinc and Iron on yield attributing characters of barley.** Redraw all tablesaccording toAuthorGuidelines.

Test weight (g)	S.E(m)±	0.239	0.239	0.477	
	CD(p=0.05)	0.693	0.693	NS	

3.3Productivity Parameters

It was observed that application of different methods of Zn and Fe both enhanced the grain yield, straw yield and biological yield of barley significantly over its control except harvest index which increased non-significantly present in table no. 4. Maximum grain yield 56.650 q ha^{-1}, straw yield 66.703 q ha^{-1}, biological yield 123.351q ha^{-1} was recorded with soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} which were found 17.77%, 14.94% and 16.22% higher to its control. Two foliar application of Zn (0.5%) produce grain yield 54.338q ha^{-1}, straw yield 64.188 q $ha^{-1}$and biological yield 118.523 q ha^{-1}which was 12.96% ,10.60% and 11.67 % higher than the yield of its respective control. A significant increase in grain yield with the application of Zn in different modes was reported by **Kumar and Verma (2008),Pooniya and Shivay (2013), Singh (2017).** Addition of Fe in different mode also influenced grain, straw and biological yield significantly over control. Highest grain yield 55.087 q ha^{-1} , straw yield 64.996 q ha^{-1} and biological yield 120.083 q $ha^{-1}$was recorded with two foliar application of Fe (0.5 %) which was found 12.77%,8.68% and 9.45%over control. Soil application of Fe@ 10 kg $FeSO_4$ ha^{-1} produced grain yield 53.700 q ha^{-1},straw yield 63.625 q $ha^{-1}$and biological yield 117.323 q ha^{-1} which was 7.58%, 6.39% and 6.94 % over control. Most of the research on methods of Fe application have shown the superiority of foliar application over soil application. These findings are in the line of the findings of **Duraisamy and Mani (2001),Sakal (2001),Ramana *et al*., (2006) and Habib (2009)**. Likewise, Zn and Fe application alone in different modes their interactions also increased grain,straw yield,biological yield but increase in grain,straw and biological yield with combined application of Zn and Fe in different mode was found non-significant. The highest grain yield 59.550 q ha^{-1}, straw yield 69.673 q $ha^{-1}$and biological yield 129.220 q $ha^{-1}$was recorded with soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} and two foliar application of Fe (0.5%) which was found 28.75%, 23.4.8% and 25.85 % higher to its respective control. These findings are further supported by the findings of **Duraisamy and Mani (2001),RamSakal (2001), Babaeian*et al*., (2012) and Singh (2017).**

Table no.-4: Effect of Zinc and Iron on productivity parameters of barley

Comment [R13]: Table 4
Redraw all tablesaccording toAuthorGuidelines

Level of Zn	**Levels of Fe**	**Mean**

	Fe_0	Fe_1	Fe_2	Fe_3	
	Grain yield (q ha^{-1})				
Zn_0	46.250	47.400	49.850	48.900	**48.100**
Zn_1	49.050	50.753	53.897	52.550	**51.563**
Zn_2	51.250	53.600	57.050	55.450	**54.338**
Zn_3	53.100	56.050	59.550	57.900	**56.650**
Mean	**49.912**	**51.951**	**55.087**	**53.700**	
Straw yield (q ha^{-1})					
Zn_0	56.423	57.307	59.567	58.827	**58.031**
Zn_1	58.813	60.497	63.653	62.323	**61.322**
Zn_2	60.937	63.407	67.090	65.320	**64.188**
Zn_3	63.030	66.080	69.673	68.030	**66.703**
Mean	**59.801**	**61.823**	**64.996**	**63.625**	
Biological yield (q ha^{-1})					
Zn_0	102.673	104.700	109.420	107.720	**106.128**
Zn_1	107.857	111.240	117.550	114.870	**112.879**
Zn_2	112.180	117.000	124.140	120.770	**118.523**
Zn_3	116.120	122.133	129.220	125.930	**123.351**
Mean	**109.708**	**113.768**	**120.083**	**117.323**	
Harvest index (%)					
Zn_0	45.040	45.270	45.547	45.387	45.311
Zn_1	45.467	45.617	45.853	45.740	45.669
Zn_2	45.680	45.807	45.950	45.910	45.837
Zn_3	45.723	45.890	46.080	45.970	45.916
Mean	45.478	45.646	45.858	45.752	
		Zn	**Fe**	**Zn x Fe**	
Grain yield	S.E(m)±	0.327	0.327	0.654	
	CD(p=0.05)	0.950	0.950	NS	
Straw yield	S.E(m)±	0.359	0.359	0.718	
	CD(p=0.05)	1.041	1.041	NS	
Biological yield	S.E(m)±	0.699	0.699	1.398	
	CD(p=0.05)	2.028	2.028	NS	
Harvest index	S.E(m)±	0.258	0.258	0.515	

5.Conclusion

The experimental results indicated that superiority in regard to growth parameters, yield components and productivity parameters *viz,* grain yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index(%) with the use of treatment combination 100% RDF + soil application of Zn @ 25 kg $ZnSO_4$ ha^{-1} + two foliar application of Fe (0.5%) gave in soil ensure highest growth parameters, yield components and productivity,of barley crop as comparison to all the treatments during 2021-2022.

6. References

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Comment [R14]: Review all references

Correct form
According toAuthor's Guidelines
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