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Effect of nutrient enrichment through zinc and iron on growth, yield attributing characters and yield of wheat (*Triticum aestivum*)

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Abstract
The experiment entitled "Effect of nitrogen fertilizer and Ferti-fortification through zinc and iron on growth and yield attributing characters of wheat (*Triticum aestivum*)" at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, (U.P.) during *rabi* season of 2021-22 and 2022-23. The experiment comprises of twelve treatments *viz.* Control, No nitrogen + Soil zinc, No nitrogen + foliar iron (0.5%), No nitrogen + foliar zinc (0.5%), No nitrogen + soil zinc + foliar zinc (0.5%), Recommended nitrogen, Recommended nitrogen + soil zinc, Recommended nitrogen + foliar zinc (0.5%), Recommended nitrogen +foliar iron (0.5%), Recommended nitrogen +foliar iron (1.0%), Recommended nitrogen + soil zinc + foliar iron (0.5%) and Recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%) were tested in randomized block design with three replications. The soil of the experimental area was sandy clay loam with low organic matter, available nitrogen, medium in available phosphorus, potassium, zinc, Iron and slightly alkaline in reaction. The result of the experiment revealed that the maximum plant height (98.10 cm & 96.81 cm), number of tillers (321.96 m^{-2} & 319.83 m^{-2}), dry matter accumulation (1255.85 g m^{-2} & 1234.05 g m^{-2}), effective tillers (311.14 m^{-2} & 304.04 m^{-2}), spike length (12.53 cm & 12.26 cm), grains $spike^{-1}$(45.68 & 45.06) and test weight (43.89 g & 43.26 g) was recorded with recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%) treatments during 2021-22 and 2022-23, respectively.

Keywords: Ferti-fortification, plant height, dry matter accumulation, effective tillers, wheat

1. Introduction

The world's most significant food crop is wheat (*Triticum aestivum* L.) is grown across 122 nations, covers 217 million ha, and produced 781.7 million tonnes of wheat. Around 777 million tonnes of wheat are used worldwide annually, and this number is predicted to rise in the future (Anonymous, 2021-22) [3]. In India, 31.6 million hectares area is under wheat cultivation, which would produce 109.53 million tonnes with productivity of 3464.5 kg ha^{-1} in 2021–2022 (Anonymous, 2021-22) [3]. About 91% of the wheat consumed in India is grown in just six states: Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, and Bihar. Uttar Pradesh holds first position with 31.28 million tonnes production of wheat. Uttar Pradesh is the state that produces the most wheat in the nation; it can have a significant impact on the country's overall wheat production. The average productivity of wheat in the U.P. is lower than the national average. It is primarily caused by a lack of resources and inadequate nutrient management techniques.

Technologies of Green Revolution have contributed enormously towards quantum jump in agricultural production in the country but have left behind multifarious issues threatening to sustainability concerns. High extent adoption of common blanket fertilizer recommendations and dependence on high analysis fertilizers has led multiple deficiencies of secondary and micro nutrients resulting low fertilizer and input use efficiencies. Zinc deficiency appeared initially followed by iron and manganese. WHO report regarding mineral deficiencies particularly Zn and Fe in human population have also become a concern and bio-fortification of agricultural produce is now a priority agenda. Fragmentation of agricultural holdings further aggravated the issues with variable nutrient supplying capacity both at the spatial and temporal scale. Crop nutrition present in small concentration play crucial role in growth and development, quality and yield formation of crops. Nitrogen is a crucial component of proteins, amino acids, nucleic acids, nucleotides, phospholipids, chlorophyll, enzymes, hormones, vitamins, and other substances. It gives plants their dark green color and enhances the quality of wheat crops. Phosphorus governs the root growth and reproductive function as a constituent of nucleic acid, phytin, phospholipids, ATP etc. Potassium promotes disease resistance, regulates water balance, strengthens stalks, builds proteins, regulates respiration, stretches water, and acts as a disease retarder, but it is ineffective without co-nutrients like nitrogen and phosphorus. Zinc, as constituent of amino acids and vitamins, helps in chlorophyll formation, involved in forming and stabilizing the tertiary structure of enzyme and other proteins.

The foundation of life is food and nutrient consumption, and people are dying in large numbers because of inadequate nutritional intake. About 30 million people died as a result of this issue in developing countries with limited resources in 2003. According to Graham, one person passes away from a disease related to diet every second. Additionally, one in three persons worldwide suffers from Fe insufficiency, whereas 10% of Americans and Canadians and 30% of those in underdeveloped nations are Zn deficient. However, common cereals like wheat frequently have insufficient levels of micronutrients, particularly iron (Fe) and zinc (Zn), and milling removes the majority of this content. This causes micronutrient deficits in areas where grains make up the majority of the human diet. It was also asserted that additional Zn and Fe applications by soil or foliar applications could promote the increased activity of Zn and Fe in the source (flag leaf and stem) during grain filling. Soil fertilization with Zn, which is typically applied as $ZnSO_4$ $7H_2O$, appears to be important for ensuring the success of bio-fortification (Cakmak *et al*., 2007) [4].

2. Materials and Methods

The field experiment was conducted at the Crop Research Center of the Sardar Vallabhbhai Patel University of Agriculture and Technology in Meerut (U.P.), which is located in the North Western Plains of the wheat growing zone and, in the Indo-Gangetic plains of Western Uttar Pradesh. Geographically, the farm is situated at 290 05' 19" North latitude, 770 41' 50" East longitudes, and 237 meters above mean sea level. The Meerut is situated on Delhi-Dehradun National Highway. This area has a semi-arid, subtropical climate with rich alluvial soil. The average annual rainfall in the area is 890 mm. Most of the rain falls between mid-June and the end of September. The last week of December through the middle of January sees periodic rain and frost, and the winter months are colder overall. The temperature can reach 44–47 °C or higher in May and June than and as low as 2-3 °C in the winter. Since July until the end of March, the mean relative humidity (7 AM) has been roughly steady at 80–90%, and following March it steadily declines to 40–50% by the end of April before returning to 80% in May. The weekly distribution of maximum and minimum temperature (ºC), relative humidity (%), wind velocity (km hr^{-1}), Evaporation rate (mm day^{-1}) and total rainfall (mm) recorded during the crop growth period (2021-22 and 2022-23). Before pursuance of the experiment, representative samples (15 cm depth) were collected from the experimental field to determine the initial physico-chemical status of the soil. Those were then subjected to mechanical and chemical analysis and results for physical and chemical properties of soil. The soil of the experimental area was sandy clay loam with low organic matter, available nitrogen, medium in available phosphorus, potassium, zinc, Iron and slightly alkaline in reaction.

The field was irrigated to have optimum moisture level for field preparation and germination. After irrigation the field was ploughed once followed by harrowing twice and planking. Each time, the operations were done by tractor drawn implements. After that, the plots were marked according to the layout plan and dressed properly with spade. Every plot of the experimental crop was treated with equal amount of nutrients, which were 150, 60, 60 and 5 kg of N, P, K and Zn per hectare respectively. Urea, Single super phosphate, Muriate of potash and Zinc sulphate was used to apply the N, P, K and Zn, respectively. At the time of sowing, a full dose of phosphorus, potash, zinc and one-third of nitrogen were applied in field. Following the initial irrigation, the rest of the nitrogen was top dressed in two equal splits at first & second irrigation in order to ensure the crop would grow well. The foliar spray of iron was applied as per treatment.

3. Result and Discussion

3.1 Plant height (cm)

Plant height increased continuously with advancement of crop age and reached maximum at harvest are presented in Table 1 and depicted in Fig. 1a & 1b. The plant height was significantly influenced by nutrient enrichment practices during both the years 2021-22.

Plant height was significantly influenced by nutrient enrichment practices and the maximum plant height was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%) which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%), but significantly higher than rest of the treatments during both the year. The lowest plant height was observed in control treatment at all the stages of crop growth during both the years. A number of studies proved that the significant effect of nutrient enrichment practices on plant height. For instance, Jat *et al.* (2013) [7], Jan *et al.* (2013) [6], Sultana *et al*. (2018) [10] and Akram *et al.* (2020) [1].

Table 1: Effect of nutrient enrichment practices on plant height at various stages of crop growth

Treatments	Plant height (cm)		Number of Tillers (m^{-2})		Dry matter accumulation (g m^{-2})	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Control	83.11	82.96	211.15	209.02	700.23	678.10
No Nitrogen + Soil Zinc	85.13	84.89	223.11	216.98	738.28	697.82
No Nitrogen + Foliar Iron (0.5%)	85.39	85.08	234.16	227.03	756.43	727.97
No Nitrogen + Foliar Zinc (0.5%)	87.22	86.83	235.24	229.11	795.11	757.25
No Nitrogen + Soil Zinc + Foliar Zinc (0.5%)	88.31	87.84	235.91	231.78	811.08	793.62
Recommended Nitrogen	89.23	88.65	307.35	306.89	1161.10	1147.97
Recommended Nitrogen + Soil Zinc	91.88	91.21	312.17	308.04	1198.90	1167.77

Recommended Nitrogen + Foliar Zinc (0.5%)	92.59	91.81	313.22	310.76	1222.30	1202.17
Recommended Nitrogen +Foliar Iron (0.5%)	91.73	90.84	311.12	307.99	1182.80	1157.67
Recommended Nitrogen +Foliar Iron (1.0%)	94.23	93.14	314.24	312.11	1206.45	1193.32
Recommended Nitrogen + Soil Zinc + Foliar Iron (0.5%)	96.69	95.48	316.11	315.98	1230.35	1205.22
Recommended Nitrogen + Foliar Zinc (0.5%) + Foliar Iron (0.5%)	98.10	96.81	319.26	317.27	1255.85	1234.05
S.Em±	0.61	0.56	2.06	2.04	11.40	13.48
CD (P= 5%)	1.80	1.67	6.08	6.03	33.66	35.60

Number of Tillers (m^{-2})

Number of tillers increased continuously with advancement of crop age up to 90 days and slightly decline thereafter are presented in Table 1 and depicted in Fig.1a & 1b. The number of tiller was significantly influenced by nutrient enrichment practices during both the years 2021-22.

Number of tillers was significantly influenced by nutrient enrichment practices, the maximum number of tiller was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%) and recommended nitrogen +foliar iron (1.0%), but significantly higher than rest of the treatments during both the year. The lowest number of tillers was observed in control treatment at all the stages of crop growth during both the years. Similar findings were reported by Akram *et al.* (2020) [1] and Melash *et al.* (2020) [9].

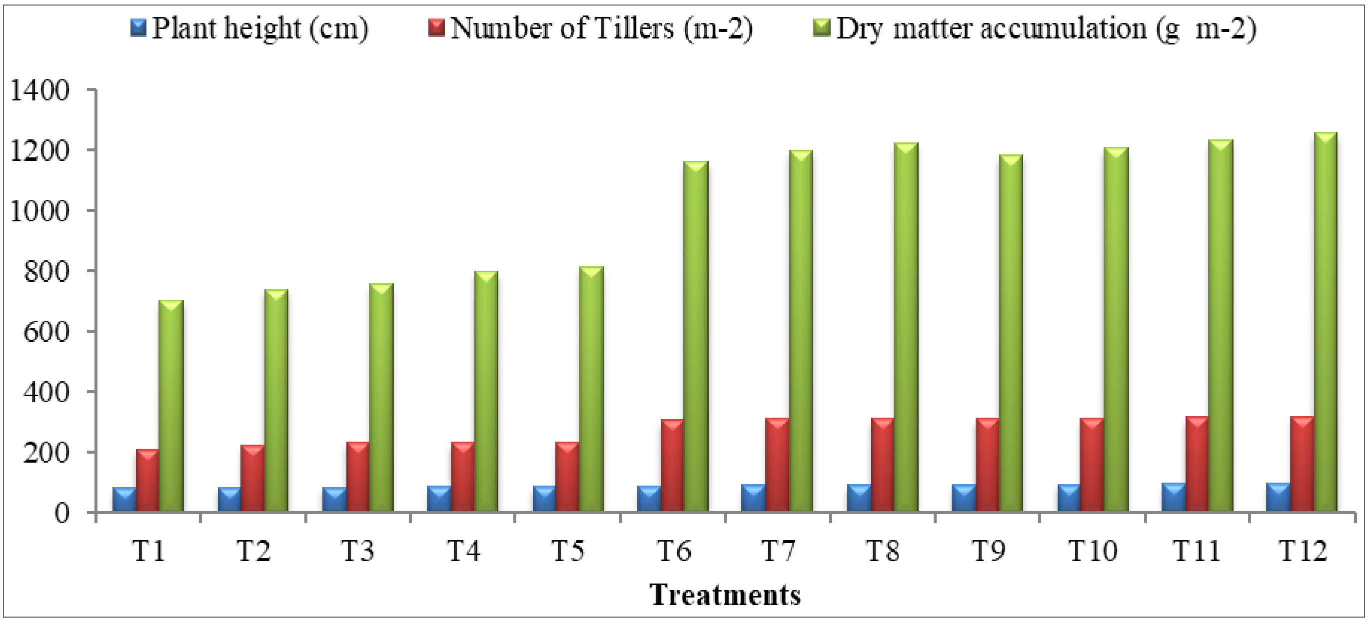

Fig 1a: Effect of nutrient enrichment practices on plant height, number of tillers and dry matter accumulation of wheat.

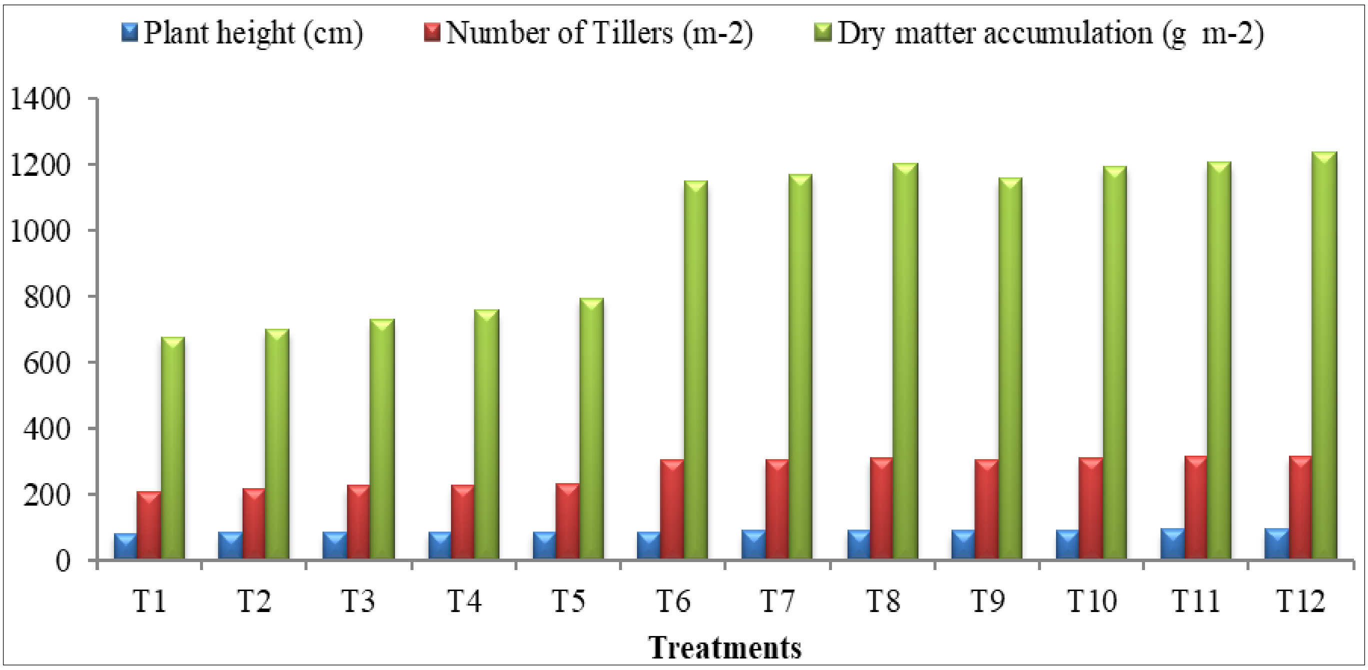

Fig 1b: Effect of nutrient enrichment practices on plant height, number of tillers and dry matter accumulation of wheat.

Dry matter accumulation (g m^{-2})

Dry matter accumulation increased continuously with advancement of crop age and reached highest at harvest are presented in Table 1 and depicted in Fig.1a & 1b. The dry matter was significantly influenced by nutrient enrichment practices during both the years 2021-22.

Dry matter accumulation was significantly influenced by nutrient enrichment practices and the maximum dry matter accumulation was observed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%) and recommended nitrogen + foliar zinc (0.5%) but significantly higher than rest of the treatments during both the year. The lowest dry matter accumulation was observed in control treatment during both the years. Similar findings were reported by Akram *et al.* (2020) [1] and Melash *et al.* (2020) [9].

Yield attributes

The data related to yield attributes are presented in Table 2 and depicted in Fig. 2a & 2b. The effective tillers were significantly influenced by nutrient enrichment practices during both the years 2021-22.

The maximum number of effective tillers was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%), recommended nitrogen + foliar iron (1.0%), recommended nitrogen + foliar iron (0.5%) and recommended nitrogen + soil zinc, but significantly higher than rest of the treatments during both the year of experiment. The lowest number of effective tiller was observed in control treatment during both the years.

The maximum spike length was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%) and recommended nitrogen + foliar iron (1.0%), but significantly higher than rest of the treatments during both the year of experiment. The lowest spike length was observed in control treatment during both the years.

The maximum number of spikelet spike^{-1} was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%) and recommended nitrogen + foliar iron (1.0%), but significantly higher than rest of the treatments during both the year of experiment. The lowest number of spikelet spike^{-1} was observed in control treatment during both the years.

The maximum number of grains spike^{-1} was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%), but significantly higher than rest of the treatments during both the year of experiment. The lowest number of spikelet grains^{-1} was observed in control treatment during both the years.

The maximum test weight was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + foliar iron (1.0%), recommended nitrogen + foliar iron (0.5%) and recommended nitrogen + foliar zinc (0.5%), but significantly higher than rest of the treatments during 2021-22, while, during 2022-23 the maximum test weight was noticed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + foliar zinc (0.5%), but significantly higher than rest of the treatments. The lowest test weight was observed in control treatment during 2022-23 the years. Similar data were reported by Ali *et al.* (2009) [2], Sultana *et al.* (2018) [10], Hasan *et al.* (2019) [5] and Malav *et al.* (2019) [8].

Table 2: Effect of nutrient enrichment practices on yield attributes of wheat crop

Treatments	Effective tiller (m^{-2})		Spike length (cm)		Number of spikelet spike^{-1}		Number of grains spike^{-1}		Test weight (g)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
Control	205.39	202.82	8.95	8.76	19.63	19.12	41.39	40.91	40.21	39.48
No Nitrogen + Soil Zinc	217.25	214.58	9.19	9.02	19.67	19.17	42.89	41.86	41.16	40.33
No Nitrogen + Foliar Iron (0.5%)	227.15	223.98	9.26	9.17	19.78	19.26	41.49	40.97	40.89	40.16
No Nitrogen + Foliar Zinc (0.5%)	229.11	224.94	9.42	9.29	19.82	19.30	41.88	41.15	40.86	40.63
No Nitrogen + Soil Zinc + Foliar Zinc (0.5%)	231.90	226.93	9.48	9.38	19.94	19.38	42.46	41.33	40.88	40.75
Recommended Nitrogen	301.31	296.79	9.92	9.69	20.30	19.86	43.80	42.54	42.68	41.97
Recommended Nitrogen + Soil Zinc	306.36	300.99	10.45	10.19	20.46	20.02	43.92	43.09	42.97	42.50
Recommended Nitrogen + Foliar Zinc (0.5%)	308.00	303.70	10.94	10.63	21.12	20.60	44.33	43.20	43.72	42.89
Recommended Nitrogen +Foliar Iron (0.5%)	306.97	298.97	11.03	10.78	22.18	21.70	44.17	43.14	43.15	41.42
Recommended Nitrogen +Foliar Iron (1.0%)	308.27	304.37	12.23	11.87	22.49	22.01	44.27	43.84	43.86	42.43
Recommended Nitrogen + Soil Zinc + Foliar Iron (0.5%)	310.15	302.37	12.27	11.98	22.62	22.22	45.62	44.42	43.02	42.49
Recommended Nitrogen + Foliar Zinc (0.5%) + Foliar Iron (0.5%)	311.14	304.04	12.53	12.26	22.72	22.25	45.68	45.06	43.89	43.26
S.Em±	1.98	1.92	0.37	0.36	0.15	0.13	0.27	0.25	0.27	0.25
CD (P= 5%)	5.85	5.67	1.10	1.07	0.44	0.38	0.81	0.75	0.78	0.74

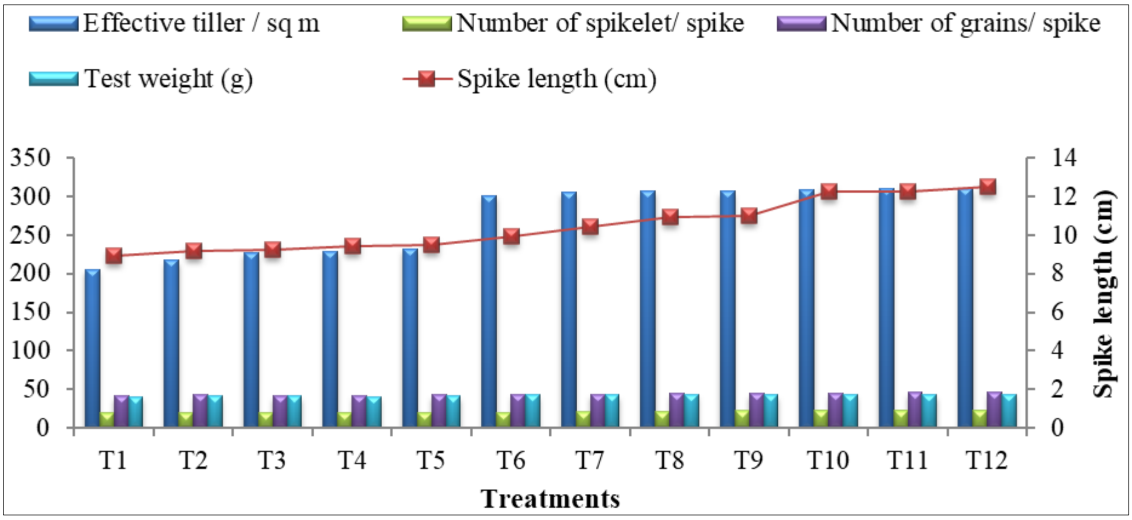

Fig 2a: Effect of nutrient enrichment practices on yield attributes of wheat crop

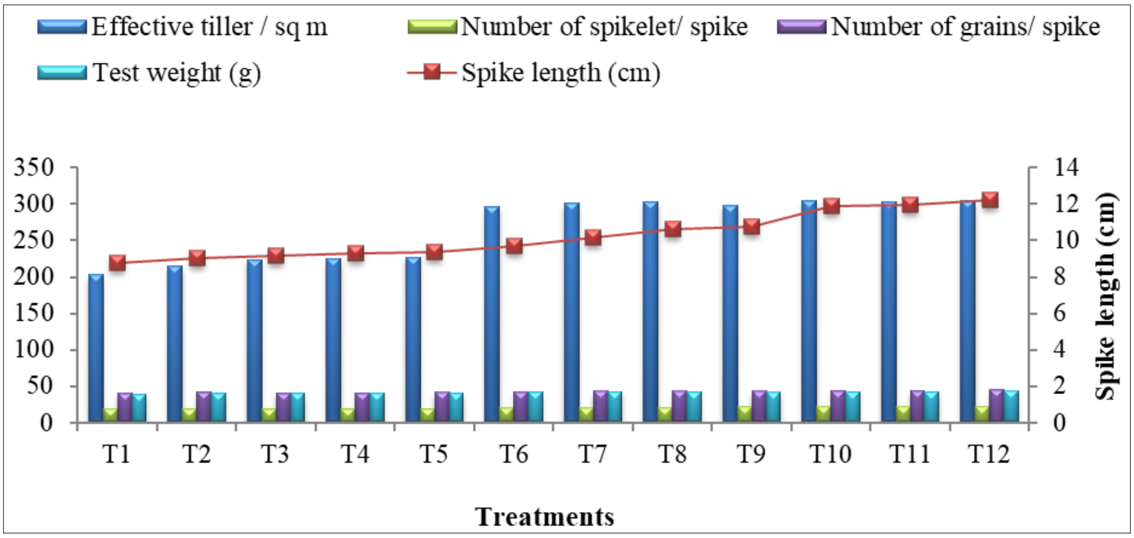

Fig 2b: Effect of nutrient enrichment practices on yield attributes of wheat crop.

Yield (q ha^{-1}): The data related to yield are presented in Table 3 and depicted in Fig. 3a & 3b. The yield of the crop was significantly influenced by nutrient enrichment practices during both the years 2021-22.

The maximum grain yield was recorded with recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%), which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%), but significantly higher than rest of the treatment during both the year. The grain yield was increased by 80.89 and 89.81 percent with the recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%) than control treatment during 2021-22 and 2022-23, respectively. The lowest grain yield was observed in control treatment during both the years of experiment.

Table 3: Effect of nutrient enrichment practices on grain and straw yield (q ha^{-1}) of wheat.

Treatments	Grain Yield (q ha^{-1})		Straw Yield (q ha^{-1})	
	2021-22	2022-23	2021-22	2022-23
Control	28.10	27.10	39.22	36.95
No Nitrogen + Soil Zinc	29.16	28.41	40.17	37.45
No Nitrogen + Foliar Iron (0.5%)	29.30	28.52	40.54	37.67
No Nitrogen + Foliar Zinc (0.5%)	29.58	28.88	39.53	38.44
No Nitrogen + Soil Zinc + Foliar Zinc (0.5%)	29.79	29.33	40.32	39.37
Recommended Nitrogen	48.10	47.29	63.61	62.48
Recommended Nitrogen + Soil Zinc	49.14	48.27	65.15	63.42
Recommended Nitrogen + Foliar Zinc (0.5%)	50.50	49.86	65.20	64.37
Recommended Nitrogen +Foliar Iron (0.5%)	49.59	48.58	64.49	64.23
Recommended Nitrogen +Foliar Iron (1.0%)	50.76	49.71	64.78	64.72
Recommended Nitrogen + Soil Zinc + Foliar Iron (0.5%)	51.52	50.28	65.02	64.20
Recommended Nitrogen + Foliar Zinc (0.5%) + Foliar Iron (0.5%)	52.83	51.44	66.06	65.40
S.Em±	0.54	0.48	0.59	0.71
CD (P = 5%)	1.60	1.42	1.75	2.10

The maximum straw yield was observed in recommended nitrogen + foliar zinc (0.5%) + foliar iron (0.5%) treatment, which remained statistically at par with recommended nitrogen + soil zinc + foliar iron (0.5%), recommended nitrogen + foliar iron (1.0%), recommended nitrogen + foliar iron (0.5%), recommended nitrogen + foliar zinc (0.5%) and recommended nitrogen + soil zinc, but significantly higher than rest of the treatments during both the year. The lowest straw yield was observed in control treatment during both the years of experiment. Similar findings have been reported by Sultana *et al.* (2018) [10] and Malav *et al.* (2019) [8].

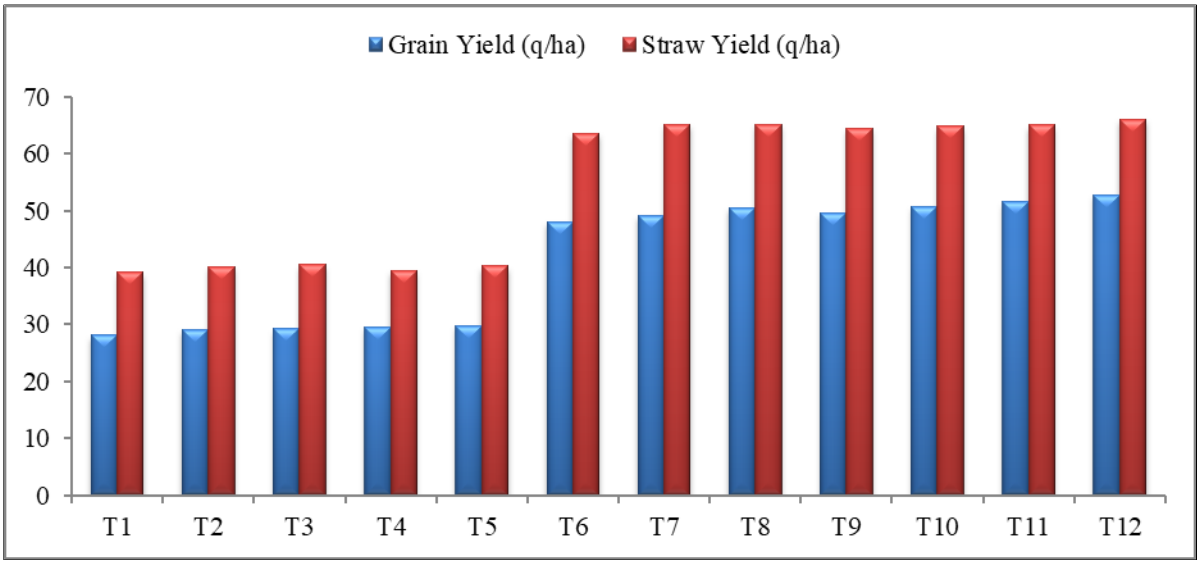

Fig 3a: Effect of nutrient enrichment practices on grain and straw yield (q ha^{-1}) of wheat

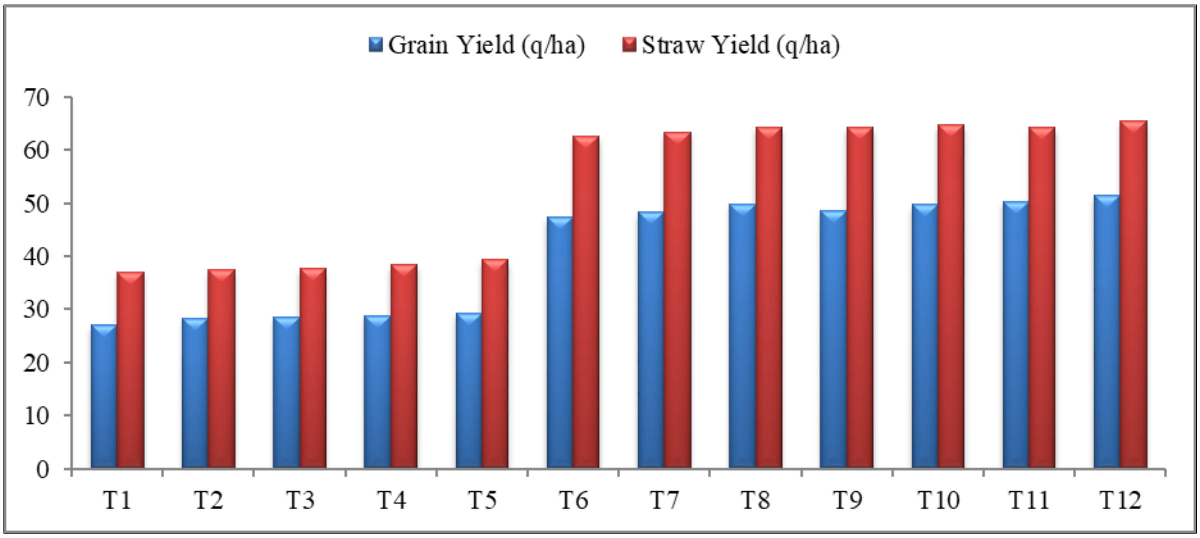

Fig 3b: Effect of nutrient enrichment practices on grain and straw yield (q ha^{-1}) of wheat

Conclusion

According to the results of the current study, application of the recommended nitrogen dose along with soil or foliar Zn + Fe resulted in the maximum plant height, tillers, dry matter accumulation, and yield attributes of the wheat crop.

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