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Impact of integrated nutrient management on growth and yield of barley (*Hordeum vulgare* L.)

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Abstract
A field study entitled "Effect of Integrated Nutrient Management on the Productivity of Barley (*Hordeum vulgare* L.)" was conducted during the rabi season of 2024-25 at the Agricultural Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur (Rajasthan). The experiment was arranged in a Randomized Block Design (RBD) with three replications. The field trial consisted 10 treatments combinations *viz.*, (i) control, (ii) 40 kg N ha^{-1}, (iii) 80 kg N ha^{-1} and (iv) 100% RDF ha^{-1}, (v) 75% RDF ha^{-1}, (vi) 75% RDF + 30 kg$ZnSO_4$ ha^{-1}, (vii) 75% RDF+ 5t FYM ha^{-1} + 30 kg$ZnSO_4$ ha^{-1} (viii) 50% RDF ha^{-1}, (ix) 50% RDF+ 30 kg$ZnSO_4$ ha^{-1} and (x) 50% RDF+ 5t FYM ha^{-1} + 30 kg$ZnSO_4$ ha^{-1}. The result showed that higher growth parameters *viz.*, plant height, number of tillers meter^{-1} row length, DMA, CGR and RGR and maximum yield attributes and yield *viz.*, spike length (9.80), number of grains spike^{-1} (44.50), test weight (42.80 g), grain yield (2490 kg ha^{-1}) and straw yield (3520 kg ha^{-1}) of barley recorded with the application of 100% RDF and found at par with the application of 75% RDF + 5 t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1}.

Keywords: Barley, integrated nutrient management, growth, yield attributes, yield

Introduction
Barley, commonly referred to as "Jau" in India, is primarily grown during the rabi season. The crop thrives at temperatures of approximately 12-15°C during its growing phase and requires around 30-32°C for proper maturation (Dahiya *et al*. 2019) [1]. Barley is more tolerant to dry heat compared to other small-grain crops. Globally, barley is produced on approximately 70 million hectares, yielding around 160 million tonnes. In India, it ranks second to wheat in terms of both area and production among rabi crops. The country cultivates barley on about 0.65 million hectares, producing roughly 0.17 million tonnes, with an average productivity of 2.4 tonnes hectare^{-1} (DES 2024) [2]. The major barely growing state in India is Rajasthan, U.P, M.P, Haryana, Punjab, H.P. and Uttarakhand. Rajasthan consistently ranks first in terms of barley acreage (0.29 m ha) in 2023-22, an acceptable reason that it shares higher production as well (52%). Dur ing the Rabi season, the average productivity in bar ley was highest in the case Punjab (3.7 t ha^{-1}), followed by Haryana (3.6 t ha^{-1}), U.P (2.9 t ha^{-1}), and Rajasthan (2.8 t ha^{-1}) (DES 2024) [2]. Barley ranks as the fourth most important cereal crop due to its high nutritional value, serving as an excellent source of protein and B vitamins. It plays a significant role in ensuring food security. Whole barley grains contain approximately 65-68% starch, 15-17% high-quality protein, 2-3% free lipids, 4-9% β-glucans, and 1.5-2.5% minerals. Its protein quality surpasses that of maize and beans, as it provides all eight essential amino acids (Mali *et al*. 2017) [3].

It is incorrect to assume that barley can grow well with little or no nitrogen (N). Barley is highly sensitive to nitrogen deficiency, which significantly affects its growth. Low nitrogen availability has been associated with reduced yield, poor grain formation, and lower grain quality, similar to the effects observed in other crops. This might worsen food insecurity (Devaraja *et al*. 2006) [4]. Among the many nutrients, barley is especially responsive to nitrogen, showing significant growth improvement when nitrogen fertilizer is applied. Nitrogen is a crucial element for barley, as it plays a central role in growth and metabolism. It forms the fundamental building blocks of proteins and nucleic acids and is essential for both internal and external metabolic activities, as well as various physiological processes in the plant (Dubey *et al*. 2018) [5]. Phosphorus (P) is vital for plant growth and metabolic activities and is the second most common nutrient deficiency in cereal crops globally, following nitrogen deficiency. It also serves as a structural component of many metabolically active compounds within plants (Singh *et al*. 2020) [6]. However, phosphorus availability in soils is often low due to its reactive nature, making it a key nutrient that can limit plant growth. Soil phosphorus interactions significantly influence both crop development and the effectiveness of applied fertilizers.

The FYM supplies all major nutrients (N, P, K, Ca, Mg, S,) necessary for plant growth, as well as micronutrients (Fe, Mn, Cu and Zn). Hence, it acts as a mixed fertilizer. The FYM improves soil physical, chemical and biological properties and soil water-holding capacity (Bhawana *et al.,* 2018) [7]. Incorporating farmyard manure (FYM) into the soil enhances both soil fertility and its physical properties, including water-holding capacity. While organic manures were once the primary source of plant nutrients in traditional agriculture, their importance declined with the widespread use of high-analysis chemical fertilizers (Singh *et al.,* 2025) [8]. Although chemical fertilizers will remain the primary tool for accelerating agricultural production, recent research suggests that a balanced use of organic manures alongside chemical fertilizers can more effectively preserve long-term soil fertility and maintain high productivity levels (Malik, 2018) [9].

Soil serves as the main source of micronutrients, which are vital for plant growth. Understanding the zinc status in soil is important for enhancing crop nutrition. Zinc plays a key role in various metabolic processes and is essential for the synthesis of chlorophyll and carbohydrates (Goswami and Pandey 2018) [10]. Zinc is essential, both directly and indirectly, for the activity of several enzymes, as well as for auxin and protein synthesis. It is thought to enhance RNA synthesis, which in turn is crucial for protein production. In many areas, crops fail to reach their normal yield despite proper application of NPK fertilizers, primarily due to zinc deficiency (Kumari, 2017) [11].

Integrated nutrient management plays a crucial role and must be carefully planned to achieve the maximum yield potential of barley. With this objective in mind, the present field experiment was conducted.

Materials and Methods

The field experiment was conducted during *rabi* seasons of 2024-25 at Agricultural Research Farm, School of Agricultural Sciences, Jaipur national University, Jaipur, Rajasthan. Soil of the experimental field was sandy in texture having pH 7.58, organic carbon (OC) (0.43%), available nutrient (N 217.30 kg ha^{-1}; P 20.28 kg ha^{-1} and K 219.20 kg ha^{-1}). The experiment was laid out in randomized block design with three replications. The field trial consisted 10 treatments combinations *viz*., (i) control, (ii) 40 kg N ha^{-1}, (iii) 80 kg N ha^{-1} and (iv) 100% RDF ha^{-1}, (v) 75% RDF ha^{-1}, (vi) 75% RDF + 30 kg$ZnSO_4$ ha^{-1}, (vii) 75% RDF+ 5t FYM ha^{-1} + 30 kg$ZnSO_4$ ha^{-1} (viii) 50% RDF ha^{-1}, (ix) 50% RDF+ 30 kg$ZnSO_4$ ha^{-1} and (x) 50% RDF+ 5t FYM ha^{-1} + 30 kg$ZnSO_4$ ha^{-1}. The barley variety 'RD 2508' was sown @ 100 kg seed ha^{-1} with spacing of 22.5 cm x 5 cm. The two irrigations are applied. All agricultural practices were kept uniform in all the plots.

Results and Discussion

Growth Parameters

The integrated nutrient management significantly enhanced the growth parameters *viz.* plant height (cm), number of tillers meter^{-1} row length, DMA (g meter^{-1} row length) at 30, 60, 90 DAS, at harvest and CGR (g meter^{-1} row length day^{-1}) at 30-60 DAS, 60-90 DAS, 90 DAS-at harvest of the barley (Table 1). The significantly maximum plant height (25.76 at 30 DAS; 70.50 at 60 DAS; 91.30 at 90 DAS and 94.05 at harvest) and number of tillers per meter row length (40.10 at 30 DAS; 75.20 at 60 DAS; 79.10 at 90 DAS and 76.90 at harvest) were recorded with the application of 100% RDF ha^{-1} and it was found statistically at par with 75% RDF + 5t FYM ha^{-1} + 30 kg $ZnSO_4$/ha^{-1}. When a new plant emerges from the seed, its root system is not fully developed and it requires nutrients immediately, which are readily supplied by chemical fertilizers. In contrast, organic manures decompose slowly, so young plants may not receive nutrients quickly enough. This is a key reason why chemical fertilizers lead to higher nutrient levels in plants during the tillering stage. The increased availability of photosynthetic metabolites and nutrients to developing reproductive structures contributes to improvements in all yield-contributing traits, ultimately enhancing overall crop yield. This effect is largely due to sufficient nitrogen availability, which promotes vigorous vegetative growth and supports cell division, cell elongation, and protein synthesis, thereby increasing the plant's photosynthetic capacity. These results were in agreement with the findings of Todarmal *et al.* (2014) [12], Kumar *et al.* (2018) [13], Parashar *et al.* (2020) [14]. Applying phosphorus fertilizer to the soil promotes the development of the plant's root system, enhancing nutrient uptake, particularly phosphorus. This, in turn, leads to improved growth parameters of the crop (Yadav *et al*., 2025) [15].

Moreover, the DMA (9.90 g meter^{-1} row length at 30 DAS; 58.60 g meter^{-1} row length at 60 DAS; 379.00 g meter^{-1} row length at 90 DAS and 384.50 g meter^{-1} row length at harvest) and CGR (1.62 g meter^{-1} row length day^{-1} at 30-60 DAS; 10.68 g meter^{-1} row length day^{-1} at 60-90 DAS and 0.183 g meter^{-1} row length day^{-1} at 90 DAS-at harvest) significantly higher with the application of 100% RDF ha^{-1} and it was found statistically at par with 75% RDF + 5t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1} (Table 1). Nitrogen, as a key component of nucleic acids, chlorophyll, and enzymes, plays a direct and crucial role in the metabolic processes of plants, particularly during the vegetative phase. Higher dry matter accumulation was observed due to active tillering and the enhanced development of growth-contributing traits. These results are also in close agreement with the finding of Terefe *et al.* (2018) [16] and Zeidan *et al.* (2007) [17]. The beneficial impact of phosphorus fertilizer on plant growth may be attributed to its involvement in numerous enzymatic reactions throughout the plant. This enhances growth efficiency, including hormone regulation and protein synthesis, as well as the metabolism of photosynthetic products. Ali *et al.* (2020) [18] also obtained similar results.

Yield attributes and yield

The different integrated nutrient management practices significantly enhanced the yield attributes *viz.* spike length (cm), number of grains spike^{-1}, test weight (g) and yield *viz.* grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and HI (%) of the barley crop (Table 2). The maximum spike length (9.80), number of grains spike^{-1} (44.50), test weight (42.80 g), grain yield (2490 kg ha^{-1}) and stover yield (3520 kg ha^{-1}) were significantly recorded with the application of 100% RDF ha^{-1} and it was found statistically at par with 75% RDF + 5 t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1}. However, the integrated nutrient management practices have non-significant effect on harvest index. The enhancement of these traits can be attributed to nitrogen application, which promoted vigorous growth during the early stages, resulting in increased plant height, a larger assimilating area, more tillers, and greater dry matter accumulation. The abundant tillering, combined with higher production and mobilization of photosynthates to reproductive organs, was primarily responsible for the improved yield attributes of barley. Similar results were also reported by Patel and Meena (2018) [19] and Neelam *et al.* (2018) [20]. Furthermore, adequate phosphorus supply enhances yield attributes by promoting root proliferation, higher nutrient uptake, and accelerated cell division and elongation. This supports greater root branching, tiller formation, plant height, and dry matter accumulation, which collectively boost leaf photosynthetic activity. Additionally, increased phosphorus availability improves the translocation of assimilates, further contributing to better yield characteristics. Similar results were reported by Sharma *et al.* (2012) [21], Satish *et al.* (2017) [22] and Korde *et al.* (2024) [23].

Table 1: Effect of integrated nutrient management on growth parameters of barley

Treatments	Plant height (cm)				Number of tillers meter^{-1} row length				DMA (g meter^{-1} row length)				CGR (g meter^{-1} row length day^{-1})		
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30-60 DAS	60-90 DAS	90 DAS - At harvest
Control	16.76	45.87	59.40	61.19	26.09	48.93	51.46	50.03	6.44	38.13	246.58	250.16	1.06	6.95	0.119
40 kg N ha^{-1}	17.90	48.98	63.43	65.34	27.86	52.25	54.96	53.43	6.88	40.71	263.32	267.14	1.13	7.42	0.127
80 kg N ha^{-1}	19.14	52.38	67.83	69.88	29.79	55.87	58.77	57.13	7.36	43.54	281.59	285.67	1.21	7.93	0.136
100% RDF ha^{-1}	25.76	70.50	91.30	94.05	40.10	75.20	79.10	76.90	9.90	58.60	379.00	384.50	1.62	10.68	0.183
75% RDF ha^{-1}	22.21	60.78	78.71	81.08	34.57	64.83	68.19	66.29	8.53	50.52	326.72	331.46	1.40	9.21	0.158
75% RDF + 30 kg $ZnSO_4$ ha^{-1}	23.79	65.12	84.33	86.87	37.04	69.46	73.06	71.03	9.14	54.13	350.08	355.16	1.50	9.87	0.169
75% RDF + 5 t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1}	25.66	70.22	90.93	93.67	39.94	74.90	78.78	76.59	9.86	58.36	377.48	382.96	1.62	10.64	0.183
50% RDF ha^{-1}	20.38	55.78	72.23	74.41	31.73	59.50	62.58	60.84	7.83	46.36	299.85	304.20	1.28	8.45	0.145
50% RDF + 30 kg $ZnSO_4$ ha^{-1}	21.41	58.61	75.90	78.19	33.34	62.52	65.76	63.93	8.23	48.72	315.07	319.64	1.35	8.88	0.152
50% RDF + 5 t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1}	22.82	62.45	80.87	83.31	35.52	66.61	70.07	68.12	8.77	51.91	335.72	340.59	1.44	9.46	0.162
S.Em±	0.29	0.80	1.03	1.06	0.45	0.85	0.89	0.87	0.11	0.66	4.28	4.34	0.02	0.12	0.002
CD (p=0.05)	0.86	2.37	3.06	3.16	1.35	2.52	2.65	2.58	0.33	1.97	12.72	12.90	0.05	0.36	0.006

Table 2: Effect of integrated nutrient management on yield attributes and yield of barley

Treatments	Yield attributes			Yield		Harvest index (%)
	Spike length (cm)	No. of grainsspike^{-1}	Test weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	
Control	6.38	28.95	27.85	1620	2467	39.64
40 kg N ha^{-1}	6.81	30.92	29.74	1730	2633	39.65
80 kg N ha^{-1}	7.28	33.06	31.80	1850	2893	39.01
100% RDF ha^{-1}	9.80	44.50	42.80	2490	3520	41.43
75% RDF ha^{-1}	8.45	38.36	36.90	2147	3220	40.00
75% RDF + 30 kg $ZnSO_4$ ha^{-1}	9.05	41.10	39.53	2300	3390	40.42
75% RDF + 5 t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1}	9.76	44.32	42.63	2480	3494	41.51
50% RDF ha^{-1}	7.75	35.21	33.86	1970	2997	39.66
50% RDF + 30 kg $ZnSO_4$ ha^{-1}	8.15	36.99	35.58	2070	3113	39.93
50% RDF + 5 t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1}	8.68	39.42	37.91	2206	3277	40.23
SEm±	0.11	0.50	0.48	28.12	31.60	0.36
CD (p=0.05)	0.33	1.49	1.44	83.54	93.89	NS

Conclusion

Based on a one-year field study on barley, it can be concluded that applying 100% RDF ha^{-1} produced the highest growth parameters, yield attributes, and overall yield. This performance was statistically comparable to the treatment combining 75% RDF + 5 t FYM ha^{-1} + 30 kg $ZnSO_4$ ha^{-1}.

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