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Effect of fertility levels and liquid biofertilizers on yield and economics of barley (*Hordeum vulgare* L.)

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Abstract

A field experiment was conducted during *Rabi* season of 2024-25 at Instructional Farm, College of Agriculture, Bhilwara (Rajasthan) with the objective to evaluate the effect of fertility levels and liquid biofertilizers on yield and economics of barley. The experiment was laid out in randomized block design (factorial) with 16 treatment combinations comprised of four fertility levels, *i.e.* control, 50% RDF, 75% RDF and 100% RDF with 4 liquid biofertilizer levels (alone or in combination), *i.e.* control, *Azotobacter*, PSB and *Azotobacter* + PSB. The results revealed that barley crop fertilized with 100% RDF recorded highest quantum of yield attributes *viz.* number of effective tillers, number of grains ear⁻¹, ear length and test weight, thereby, increasing the grain yield, straw yield and net return which were at par with 75% RDF but significantly higher over rest of fertility levels. However, highest B:C ratio was reflected by crop under influence of 75% RDF followed by 100% RDF. Similarly, seed inoculation with *Azotobacter* + PSB significantly improved all yield attributes of barley. Maximum grain yield, straw yield, net return and B:C ratio were also observed under combined seed inoculation with *Azotobacter* + PSB, which was followed by inoculation with *Azotobacter* alone. Furthermore, significant interaction was observed between fertility levels and liquid biofertilizers on grain yield, net returns and B:C ratio of barley crop. Application of 100% RDF combined with seed inoculation of *Azotobacter* + PSB recorded statistically higher values of grain yield, net return and B:C ratio over other treatments. The study concludes that higher fertility level (100% RDF) combined with seed inoculation with biofertilizers (*Azotobacter* + PSB) significantly enhances grain yield, net returns and B:C ratio of barley crop.

Keywords: Barley, fertility levels, *Azotobacter*, PSB, yield, economics

Introduction

Barley (*Hordeum vulgare* L.) is considered the fourth most significant cereal crop globally, following wheat, rice, and maize. It accounts for approximately 7% of total global cereal production and 15% of coarse grain consumption. Known for its resilience, barley can thrive in challenging environmental conditions, including drought, salinity, and alkalinity. Barley is highly valued for its nutritional and medicinal benefits, making it a key ingredient in Ayurvedic medicine. It is used to treat various ailments such as fever, the common cold, asthma, skin conditions, sore throats, urinary problems, and digestive issues. Moreover, barley is commonly included in a variety of bakery products and recipes. Every 100 grams of barley grain contains 10.6 g of protein, 2.1 g of fat, 64 g of carbohydrates, 50 mg of calcium, 3 g of crude fiber, 6 mg of iron, 31 mg of vitamin B1, 0.10 mg of vitamin B2, and 50 µg of folate (Vaughan *et al.*, 2006)^[21]. Globally, barley occupies an area of 46.25 million ha giving 145.74 million tonnes of grain yield with an average of 3151.2 kg ha⁻¹ (FAO, 2024). In India, barley was grown on 0.61 million ha area, producing 1.92 million tonnes with an average yield of 3159 kg ha⁻¹. Rajasthan is the leading state, accounting for over 62% of the production and 52% of the cultivated area, followed by Uttar Pradesh. In Rajasthan, barley was cultivated on 0.33 million ha area, with production of 1.22 million tonnes, with an average productivity of 3707 kg ha⁻¹ (Anonymous, 2024-25). The average productivity of barley is far behind the attainable yield of around 5.0 t ha⁻¹, the reasons being water and nutritional stresses. Being a cereal crop, it requires considerable amounts of major nutrients, particularly nitrogen (N) and phosphorus (P) for harnessing potential yield. Adequate mineral fertilization is considered to be one of the most important prerequisites in this respect. Nitrogen and Phosphorus play a vital role in plant growth and

development. Since long, chemical fertilizers alone are used as a source of these nutrients. The continuous and exclusive use of inorganic fertilizers results in various issues, such as micronutrient deficiencies, nutrient imbalances in plant and soil systems, increased pest attacks, environmental degradation, and a decline in soil health. One possible way to decrease our dependence on chemical fertilizers is the use of biofertilizers. A biofertilizer is an organic fertilizer enhanced with beneficial microorganisms. These organic resources support plant growth by being converted into a form that plants can absorb, through the action of microorganisms, plant associations, or interactions. *Azotobacter* are abiotic, free-living soil microbes which play an important role in the nitrogen cycle in nature and binding atmospheric nitrogen which is inaccessible to plants. Inoculation with *Azotobacter* has been found to reduce the requirement of chemical fertilizer upto 50% (Soleimanzadeh and Gooshchi 2013) ^[19]. Phosphorus solubilizing bacteria (PSB) plays an important role in converting insoluble phosphate and applied phosphorus into available form resulting in higher crop yields (Gull *et al.*, 2004) ^[7]. Among the whole microbial population in soil, PSB constitute 1 to 50% in P solubilization potential (Chen *et al.*, 2006) ^[3]. It is essential to determine the optimal and well-balanced level of fertilizers combined with these inoculations for improved barley production. Therefore, keeping in view of above facts the present study has been undertaken to arrive at an economically viable treatment for enhancing productivity of barley.

Materials and Methods

The field experiment was conducted at the Instructional Farm, College of Agriculture, Bhilwara (Rajasthan) during *Rabi* season of 2024-2025. The experimental soil was clay-loam in texture, alkaline in reaction (7.82), medium in organic carbon (0.59), medium in available nitrogen (309.42 kg ha⁻¹), high in available phosphorus (22.58 kg ha⁻¹) and also high in available potassium (379.26 kg ha⁻¹). The experimental layout followed a factorial randomized block design (FRBD) with three replications and 16 treatment combinations comprised of four fertility levels, *i.e.* control, 50% RDF, 75% RDF and 100% RDF with 4 liquid biofertilizer levels (alone or in combination), *i.e.* control, *Azotobacter*, PSB and *Azotobacter* + PSB. Barley variety 'RD 2899' was used as a test crop. The total quantity of phosphorus and half dose of nitrogen were drilled in furrows before sowing of seed. Remaining half dose of nitrogen was top dressed at the time of first irrigation. The seeds were treated with liquid biofertilizers using 7 ml kg⁻¹ seed through standard procedure 2-3 hours before sowing as per treatment. The seeds were sown in furrow opened at the depth of about 4-5 cm using seed rate of 100 kg ha⁻¹ keeping inter row spacing of 22.5 cm.

Results and Discussion

Yield attributes

Fertility levels

The results indicated that fertility levels significantly affected all the yield attributes (Table 1). The application of 100% RDF recorded highest number of effective tillers (88.94 m⁻¹ row length), number of grains ear⁻¹ (31.27) and ear length (8.32 cm)

which were significantly higher than 50% RDF and control by 16.10 and 21.43%, 13.37 and 18.58%, and 9.18 and 10.19%, respectively but was at par with 75% RDF. The highest test weight (50.72 g) was also obtained under 100% RDF which was significantly higher than rest of fertility levels.

Adequate fertilization markedly enhanced overall crop growth through increased dry matter accumulation, which resulted from improvements in both morphological traits and photosynthetic efficiency, along with greater nutrient uptake. This improvement ensured enhanced availability of nutrients and metabolites for the growth and development of reproductive structures, thereby enabling the crop to express its genetic potential more effectively. The higher crop growth rate (CGR) observed under adequate fertilization, reflected by greater dry matter production, likely reduced intra-plant competition for photosynthates and nutrients between the main shoot and tillers, as well as among tillers themselves, resulting in improved tiller survival up to harvest. Similar responses in barley have been reported by Narolia *et al.*, (2013) ^[5] and Singh (2017) ^[18]. The beneficial effect of fertilizer application on grains ear⁻¹ may be attributed to its pronounced role in carbohydrate synthesis, photosynthetic activity, and cell division and elongation. Moreover, improved assimilatory surface during reproductive development and enhanced nutrient availability under adequate fertilization provided favourable conditions for grain growth, which was reflected in increased individual grain weight, expressed as higher test weight.

Liquid biofertilizers

The barley crop responded significantly in respect of yield attributes upon inoculation of seed with different liquid biofertilizers (Table 1). Combined seed inoculation with *Azotobacter* + PSB reflected highest quantum of number of effective tillers (88.94 m⁻¹ row length), number of grains ear⁻¹ (31.27) and ear length (8.32 cm) which were significantly higher than control by 23.39, 28.59 and 8.39% respectively. It was statistically higher than sole inoculation with *Azotobacter* and PSB alone also. The highest test weight (48.55 g) was also obtained under combined seed inoculation with *Azotobacter* + PSB which was closely followed by sole inoculation with *Azotobacter* and PSB alone but significantly higher than control (46.07 g) by 5.38%.

It is believed that *Azotobacter* + PSB produces phytohormones, antibacterial and antifungal compounds which stimulates root system and changes root morphology which in turn affect the assimilates of nutrients thus influence the development of reproductive structures. Amongst phytohormones, auxin, gibberellin and cytokinin are considered to play a vital role at early stage (vegetative) by affecting bud formation therefore development of effective tillers. While at later stage (reproductive) it influences first phase of grain growth through promotion of cell division and buildup of its storage capacity and thereafter retardation of senescence and keeping surface green for greater period thus increase grain growth period. These findings corroborate with earlier reports by Kumawat *et al.*, (2016), Jat, 2021 ^[10] and Athnere *et al.*, (2024) ^[2].

Table 1: Effect of fertility levels and liquid biofertilizers on yield attributes of barley

Treatment	Yield attributes			
	No. of effective tillers (m ⁻¹ row length)	No. of grains ear ⁻¹	Ear length (cm)	Test weight (g)
Fertility (%RDF)				
Control	73.24	26.37	7.55	44.89
50	76.60	27.58	7.62	46.47
75	87.69	31.07	8.23	48.63
100	88.94	31.27	8.32	50.72
SEm ±	1.62	0.438	0.098	0.299
C.D. at 0.05	4.68	1.265	0.282	0.863
Liquid biofertilizers				
Control	73.09	25.39	7.62	46.07
<i>Azotobacter</i>	85.42	31.02	7.95	48.18
PSB	77.76	27.23	7.89	47.90
<i>Azotobacter</i> + PSB	90.19	32.65	8.26	48.55
SEm ±	1.62	0.438	0.098	0.299
C.D. at 0.05	4.68	1.265	0.282	0.863

Yield

Fertility levels

The results showed that fertility levels had significant influence on grain, straw and biological yields of barley (Table 2). The barley crop fertilized with 100% RDF gave the highest grain (4329 kg ha⁻¹), straw (5437 kg ha⁻¹) and biological yields (9766 kg ha⁻¹) which was found at par with 75% RDF but was significantly higher than 50% RDF and control. However, fertility levels failed to exert any significant influence on harvest index of barley.

The maximum grain yield obtained with the application of 100% RDF can be ascribed to its pronounced influence on both vegetative and reproductive growth. Since grain yield in barley is the cumulative outcome of various yield-attributing characters, the superior performance of these components under adequate fertilization appears to be the primary reason for the significantly higher grain yield. The significant increase in straw yield with the application of 100% RDF may be attributed to its direct effect on dry matter production at successive growth stages through improved photosynthetic efficiency, as well as its indirect effects via increased plant height and number of tillers. The findings of the present study corroborate those of Kumar *et al.*, (2013) [12] and Prasad *et al.*, (2019) [17], who reported that adequate and balanced fertilization improves the nutritional status of crops, thereby facilitating optimal expression of growth, yield components, and final yield in barley.

Liquid biofertilizers

Seed inoculation with liquid biofertilizers significantly

influenced grain, straw and biological yields of barley (Table 2). The highest grain (4308 kg ha⁻¹), straw (5399 kg ha⁻¹) and biological yields (9707 kg ha⁻¹) were reflected by crop under the influence of combined seed inoculation with *Azotobacter* + PSB which were closely followed by inoculation with *Azotobacter* alone. However, grain, straw and biological yields under combined seed inoculation with *Azotobacter* + PSB were significantly higher than sole inoculation with PSB and Control by 9.61 and 17.89%, 8.32 and 14.84%, and 8.89 and 16.20% respectively. The liquid biofertilizers failed to exert any significant influence on harvest index of crop.

The marked increase in yield with the inoculation of barley seed with *Azotobacter* + PSB can be ascribed not only to adequate supply of assimilates/nutrients but also to their pivotal role in improving fertilizer use efficiency as well as soil fertility by promoting soil microbial activities, narrow down C: N ratio, decline in bulk density and increase in water holding capacity at low moisture levels. The beneficial effect of liquid biofertilizers on malt barley productivity was also reported by several researchers (Prakash *et al.*, 2015; Chopra *et al.*, 2016; Tomar *et al.*, 2016; Singh, 2017; Jat, 2021; Athnere *et al.*, 2024) [16, 4, 20, 18, 10, 2]. The increase in straw yield due to inoculation of seed with *Azotobacter* + PSB could be partly attributed to its direct influence on dry matter production by each vegetative part and indirectly through increased morphological parameters of growth (plant height and tillers m⁻¹ row length). The results of investigation corroborated findings of Jat *et al.*, (2018) [9], Malik (2019) [14], Jatinderpal (2021) and Kumawat (2021) [13].

Table 2: Effect of fertility levels and liquid biofertilizers on yield of barley

Treatment	Yield			
	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	HI (%)
Fertility (%RDF)				
Control	3649	4489	8138	44.84
50	3764	4943	8707	43.19
75	4290	5391	9681	44.31
100	4329	5437	9766	44.28
SEm ±	88.14	116.43	160.71	0.685
C.D. at 0.05	254.58	336.26	464.18	NS
Liquid biofertilizers				
Control	3654	4701	8355	43.74
<i>Azotobacter</i>	4140	5177	9317	44.49
PSB	3930	4984	8914	44.02
<i>Azotobacter</i> + PSB	4308	5399	9707	44.36
SEm ±	88.14	116.43	160.71	0.685
C.D. at 0.05	254.58	336.26	464.18	NS

Table 2a: Interactive effect of fertility levels and liquid biofertilizers on grain yield (kg ha⁻¹) of barley

F X B	F ₀	F ₁	F ₂	F ₃
B ₀	3029.43	3718.05	4205.49	3663.94
B ₁	3607.28	4141.59	4556.43	4254.80
B ₂	3914.97	3325.53	3928.91	4551.45
B ₃	4045.59	3869.17	4469.86	4847.52
SEm ±	176.294			
C.D. (P=0.05)	509.1738			

Interaction effect of fertility levels and liquid biofertilizers on grain yield

Results (Table 2a) revealed that the interaction effect of fertility levels and liquid biofertilizers had a substantial impact on grain yield of barley. The highest grain yield of 4847.52 kg ha⁻¹ was obtained with F₃B₃ (combination of 100% RDF and seed inoculation with *Azotobacter* + PSB) which was at par with F₂B₃ (75% RDF along with *Azotobacter* + PSB) and F₃B₂ (100% RDF along with PSB alone). However, this treatment combination significantly outperformed the control receiving neither fertilizer nor biofertilizer (3029.43 kg ha⁻¹).

The significantly higher grain yield of barley obtained with the application of 100% RDF in combination with *Azotobacter* + PSB can be attributed to the synergistic interaction between inorganic fertilizers and liquid biofertilizers. Application of 100% RDF ensured an adequate and balanced supply of essential nutrients, particularly nitrogen and phosphorus, throughout the crop growth period, while inoculation with *Azotobacter* and PSB further enhanced nutrient availability through biological nitrogen fixation and solubilization of native and applied phosphorus. Consequently, this integrated nutrient management approach resulted in improved growth and yield attributes, culminating in the highest grain yield of barley.

Economics

Fertility levels

The results (Table 3) showed that net return and B:C ratio of barley was significantly influenced by varying fertility levels. Application of 100% RDF recorded highest net return (₹ 89205 ha⁻¹) which was closely followed by 75% RDF (₹ 88539 ha⁻¹) but was significantly higher than 50% RDF and control by 19.30 and 25.92% respectively. However, highest B:C ratio (2.46) was reflected by crop under influence of 75% RDF which was found at par with 100% RDF (2.45) and was statistically superior to 50% RDF and control by 16.89 and 20.30% respectively.

The highest net return and benefit-cost (B:C) ratio recorded under the application of 100% RDF can be attributed to the substantial increase in grain and straw yield of barley, which more than compensated for the comparatively higher cost of fertilizer application. Adequate and balanced supply of nutrients at 100% RDF enhanced crop growth, tillering, and yield attributes, leading to significantly higher biological and economic yield. Although fertilizer cost increased with higher fertility levels, the marginal yield gain obtained at 100% RDF was proportionately greater than the additional cost incurred, resulting in superior economic returns. The results of investigation corroborated findings of Jat *et al.*, (2018) [9], Malik (2019) [14].

Liquid biofertilizers

As per results (Table 3), barley crop responded significantly in respect of economics upon seed inoculation with liquid biofertilizers. Combined inoculation with *Azotobacter* + PSB recorded highest net return (₹ 88997 ha⁻¹) and B:C ratio (2.47) which were found to be at par with inoculation with *Azotobacter* alone (2.37) but significantly higher than inoculation with PSB alone and control by 13.46 and 24.82% and 12.14 and 22.58%, respectively.

The highest net return and B:C ratio obtained with inoculation of *Azotobacter* + PSB were achieved due to the synergistic effect of the two biofertilizers in enhancing nutrient availability and crop productivity at a relatively low cost of application. Since the cost of liquid biofertilizer inoculation is comparatively low, the additional expenditure was minimal, whereas the yield advantage was substantial. In contrast, sole application of either *Azotobacter* or PSB provided limited benefits, and the control treatment resulted in poor productivity due to nutrient constraints. Therefore, the higher returns obtained under *Azotobacter* + PSB inoculation were mainly due to increased yield at lower input cost, leading to maximum net return and B:C ratio. Similar findings were reported by Jat, 2021 [10] and Athnere *et al.*, (2024) [4].

Interaction effect of fertility levels and liquid biofertilizers on economics

Data presented in Table 3a and Table 3b indicates that the interaction between fertility levels and biofertilizers exerted a significant effect on net returns and B:C ratio of barley. The treatment F₃B₃ (combination of 100% RDF with *Azotobacter* + PSB) recorded the highest net return of ₹ 103289 ha⁻¹, which was statistically at par with treatment F₂B₃ i.e. 75% RDF along with *Azotobacter* + PSB (₹ 93217 ha⁻¹) and treatment F₃B₂ i.e. 100% RDF along with PSB (₹ 95385 ha⁻¹) as the difference remained within the critical range. However, this treatment combination was significantly superior over the control receiving neither fertilizers nor biofertilizers (₹ 54173 ha⁻¹). Similarly, the treatment F₃B₃ recorded the highest B-C ratio of 2.81, which was statistically at par with treatment F₂B₃ (2.57) and treatment F₃B₂ (2.62). However, this treatment combination was significantly superior over the control receiving neither fertilizers nor biofertilizers (1.5814).

The significantly higher net return and benefit-cost (B:C) ratio obtained under the combined application of 100% RDF along with *Azotobacter* + PSB can be attributed to the synergistic interaction between adequate chemical fertilization and effective biological inoculation, which maximized economic productivity of barley. Although the cost of cultivation was slightly higher due to fertilizer and biofertilizer inputs, the incremental increase in yield and marketable produce was proportionately much greater than the additional cost incurred, leading to maximum gross and net returns. Hence, the integration of 100% RDF with *Azotobacter* + PSB proved to be the most economically efficient treatment, reflecting the importance of integrated nutrient management for profitable barley production. Similar results were supported by Jangir *et al.*, (2016) [8] and Game *et al.*, (2020) [6].

Table 3: Effect of fertility levels and liquid biofertilizers on economics of barley

Treatment Fertility (%RDF)	Economics		
	Gross Return (₹ ha ⁻¹)	Net Returns (₹ ha ⁻¹)	B:C Ratio
Control	105427	70838	2.0462
50	110277	74773	2.1059
75	124501	88539	2.4617
100	125625	89205	2.4473
SEm ±	2209	2209	0.064
C.D. at 0.05	6380	6380	0.184
Liquid biofertilizers			
Control	106586	71300	2.0168
<i>Azotobacter</i>	120018	84416	2.3677
PSB	114278	78642	2.2045
<i>Azotobacter</i> + PSB	124948	88997	2.4722
SEm ±	2209	2209	0.064
C.D. at 0.05	6380	6380	0.184

Table 3a: Interactive effect of fertility levels and liquid biofertilizers on net returns (₹ ha⁻¹) of barley

F X B	F ₀	F ₁	F ₂	F ₃
B ₀	54173	73525	86544	70957
B ₁	69460	85046	95972	87188
B ₂	77964	62796	78423	95385
B ₃	81756	77726	93217	103289
SEm ±	4418			
C.D. (P=0.05)	12760			

Table 3b: Interactive effect of fertility levels and liquid biofertilizers on benefit-cost ratio of barley

F X B	F ₀	F ₁	F ₂	F ₃
B ₀	1.5814	2.0904	2.4290	1.9662
B ₁	2.0092	2.3965	2.6700	2.3951
B ₂	2.2529	1.7678	2.1796	2.6177
B ₃	2.3412	2.1689	2.5683	2.8103
SEm ±	0.1236			
C.D. (P=0.05)	0.3570			

Conclusion

Based on the results emanated, it is concluded that combined application of 100% RDF + seed inoculation with *Azotobacter* + PSB reflected maximum quantum of grain and straw yields and achieved higher net return and B:C ratio over rest of treatments.

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