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Research Paper

Effects of integrated nutrient management on yield and economics of barley (*Hordeum vulgare*)

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2017–18 and 2018–19 Udaipur, Rajasthan, to study the nutrient status of plant and soil as influenced under integrated nutrient management in barley (*Hordeum vulgare* L.). The experiment was laid out in randomized block design (factorial), comprising combinations of 6 fertility levels and 4 liquid bio-inoculants. The results indicated that, application of 125% recommended dose of fertilizers (RDF) in conjunction with 5 t farm yard manure (FYM)/ha had significant effect on yields (grain, straw and biological yield) which was at par with 100% RDF + 5 t FYM/ha. However, both these fertility levels significantly increased the grain weight/ear over application of 75% RDF + 5 t FYM/ha, 125% RDF, 100% RDF and 75% RDF during both years. Both 125% RDF + 5 t FYM/ha and 100% RDF + 5 t FYM/ha fetched net returns of ₹66,492 and 64,933 with benefit: cost ratio 2.15 and 2.14, respectively. The barley crop under the influence of conjoint inoculation with liquid bio–fertilizers, consisting combination of *Azotobacter* + *Azospirillum* + phosphates solubilizer + plant growth-promoting *rhizobacteria* (PGPR) recorded significantly higher grain, straw and biological yields and was found at par with inoculation of *Azotobacter* + PSB inoculation, and both these treatments significantly influenced the grain, straw and biological yields. Inoculation of barley seed with liquid bio inoculant consisting combination of *Azotobacter* + *Azospirillum* + Phosphates solubilizer + PGPR recorded maximum net returns (67,906) and benefit: cost ratio 2.44 closely followed by seed inoculation with liquid bio inoculant *Azotobacter* + PSB with net returns of 65,006 and benefit: cost ratio of 2.31, registering significantly higher over inoculation with *Azotobacter* and PSB alone.

Key words: *Azotobacter, Azospirillum,* barley, phosphates solubilizer, plant growth-promoting *rhizobacteria*, recommended dose of fertilizer

Barley is an important winter (*rabi*) cereal crop of India. Being the most dependable crop in alkali soils and areas where frost or drought occurs, it is cultivated in almost all parts of the world. Among the cereals, it ranks fourth with respect to area and production after wheat, rice and maize.

The average productivity of barley in the state is far behind the attainable yield of 4.0–5.0 t/ha; 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 pre-requisites in this respect. Despite the application of recommended quantities of major nutrients, the increase in yield is not encouraging. Nitrogen is the most important nutrient for plant growth and development. It is an integral part of chlorophyll, which is essential for photosynthesis. Being the constituent of protoplasm and chlorophyll, it is also associated with the activity of every living cell. Phosphorus nutrition plays key role in plant metabolism. In plant nutrition, organic manures are potential sources of micro-nutrient, improves soil structure by providing binding action to soil aggregates, increases water-holding and buffering capacity of soils. 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.

Biofertilizers play a very significant role in improving

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soil fertility by fixing atmospheric N, both, in association with plant roots and without it, solubilize insoluble soil phosphates and produces plant growth substances in the soil. *Azotobacter* is abiotic, free-living soil microbes which plays an important role for the N cycle in nature and binding atmospheric N which is inaccessible to plants. Inoculation with *Azotobacter* reduces the requirement of chemical fertilizer up to 50% (Soleimanzadeh and Gooshchi, 2013). Phosphorus-solubilizing bacteria (PSB) plays an important role in converting insoluble P (chemically fixed and applied) into available form resulting in higher crop yields (Gull *et al.,* 2004). Among the whole microbial population in soil, PSB constitutes 1 to 50 per cent in P solubilization potential (Chen *et al*., 2006). Plant Growth Promoting Rhizobacteria (PGPR) are a heterogeneous group of bacteria that can be found in the rhizosphere, at root surfaces and in association with roots, which can improve the extent or quality of plant growth directly or indirectly (Joseph *et al*., 2007). Therefore, keeping in view of above facts the present study has been undertaken to arrive at an economically viable treatment for enhancing productivity.

MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2017–18 and 2018–19 at Rajasthan College of Agricultue, Maharana Pratap University of Agriculture and Technology, Udaipur. The soil of experimental site was clay loam, slightly alkaline, medium in available N (287.60–288.30 kg/ha), medium in available P (18.80–20.50 kg/ha) and high in available K status (338.70–346.40 kg/ha). In both seasons, crop sown on 19 and 21 November during 2017–18 and 2018–19, respectively, and harvested on 18 March 2018 and 23 March 2019. The total rainfall was 6.4 mm during 2017–18 whereas it was 1.0 mm during 2018–19. The maximum and minimum temperature during crop-growing season ranged between 23.5–37.8°C and 5.2–19.8°C during *rabi* 2017–18, respectively. The corresponding temperature fluctuations during the second year (2018–19) were between 21.6 and 39.4°C and 4.1 and 20.1°C, respectively. The experiment was laid out in randomized block design (factorial). The treatments comprising combinations of 6 fertility levels (75% RDF 45 kg N and 22.5 kg P_2O_5, 100% RDF 60 kg N and 30 kg P_2O_5, 125% RDF 75 kg N and 37.5 P_2O_5, 75% RDF + 5 tonnes FYM/ha, 100% RDF + 5 t FYM/ha and 125% RDF + 5 t FYM/ha, and 4 liquid bio inoculants viz. *Azotobacter*, PSB, *Azotobactor* + PSB and *Azotobactor* + *Azospirillum* + phosphates solubilizer + PGPR (plant growth promoting rhizobacteria) at the rate 5 ml/kg seed. These 24 treatment combinations were replicated thrice. Barley variety 'RD 2786' was used as a test crop. The seeds were sown in furrow opened at the depth of about 4–5 cm using seed rate of 100 kg/ha, with inter-row spacing of 22.5 cm.

RESULTS AND DISCUSSION

Fertility levels

The results showed that fertility levels had significant influence on grain, straw and biological yields of barley during both the years (Table 1). The barley crop fertilized with 125% RDF in conjunction with 5 t FYM/ha gave the highest grain, straw and biological yields which was found

Table 1. Effects of integrated nutrient management on yield of barley (pooled data of 2017–18 and 2018–19)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Net returns (₹ha)	Benefit: cost ratio
Fertility levels					
75% RDF	3.65	6.11	9.77	45,612	1.85
100% RDF	4.13	6.65	10.78	53,344	2.11
125% RDF	4.34	6.90	11.24	56,532	2.19
75% RDF + 5 t FYM/ha	4.46	7.18	11.65	55,355	1.86
100% RDF + 5 t FYM/ha	5.07	7.71	12.78	64,933	2.14
125% RDF + 5 t FYM/ha	5.20	7.79	12.99	66,492	2.15
SEm±	0.08	0.12	0.21	1,116	0.04
CD (P=0.05)	0.22	0.34	0.60	3,134	0.11
Liquid bio inoculants (5 ml/kg seed)					
Azotobacter	3.97	6.80	10.77	49,177	1.78
Phosphorus Solubilizing Bacteria	3.80	6.57	10.37	46,090	1.67
Azotobacter + PSB	4.99	7.31	12.30	65,006	2.31
Azotobazter + Azospirillum + Phoaphates solubilizer + PGPR	5.12	7.57	12.69	67,906	2.44
SEm±	0.06	0.10	0.17	975	0.03
CD (P=0.05)	0.18	0.28	0.49	2,961	0.09

75% recommended dose of fertilizer; 100% recommended dose of fertilizer; 125% recommended dose of fertilizer

at par with 100% RDF + 5 t FYM/ha; however, both these fertility levels significantly increased the grain yield over application of 75% RDF + 5 t FYM/ha, 125% RDF, 100% RDF and 75% RDF. Further analysis of data indicated that, 75% RDF + 5 t FYM/ha significantly increased the grain, straw and biological yields over the application of 100% RDF and 75% RDF which was remained at par with application of 125% RDF. Barley crop fertilized with 125% RDF + 5 t FYM/ha significantly increased grain, straw and biological yield by 0.86, 0.89 and 1.74 t/ha respectively over 125% RDF. This fertility level was closely followed by application of 100% RDF + 5 t FYM/ha and enhanced grain, straw and biological yields by 0.94, 1.06 and 2.00 t/ha respectively, over 100% RDF. Both 125% RDF + 5 t FYM/ha and 100% RDF + 5 t FYM/ha fetched net returns of 66,492 and 64,933 with B : C ratio of 2.15 and 2.14, respectively.

It has been well emphasized that conjoint application of chemical fertilizer and organic manure significantly improved the overall growth of crop in term of dry matter accumulation/unit area by virtue of its impact on morphological and photosynthetic component of growth along with accumulation of nutrients. This indicates greater availability of nutrients and metabolites for growth and development of each reproductive structure which ultimately led to realization of their genetic potential up to the highest level. A faster growth rate in terms of dry-matter a production as evinced from higher Crop Growth Rate and Relative Growth Rate under the influence of adequate fertilization (chemical + organic manure) might have played a significant role reducing competition for photosynthates and nutrients with mother shoots as well as between tillers resulting in their greater survival till harvest. On the other hand, adequate supply of photosynthates owing to higher photosynthetic efficiency at ear emergence might have enhanced number of flowers and their fertilization, resulting in higher number of filled spikelet and grains/ear. This is well reflected from increase in weight of individual grain expressed in term of test weight. Since grain yield/ear is dependent on number of grains/ear and weight of individual grain, thus highest grain yield/ear under adequate fertilization could be ascribed to the improvement in both these parameters. FYM is source of organic matter is also known to favorably improve soil structure, increase water-holding capacity and provide energy for nitrogen fixation by free living heterotrophic micro-organisms. FYM was often found to be superior to inorganic fertilizers because of the release of aliphatic, aromatic hydroxyl acids, humates and lignin that exert dual benefits to improve the physical conditions of the soil (Sarangi *et al*., 2014). Thus, significant

Table 2. Treatment wise cost of cultivation, yield and economic return

Treatment combination	Yield (t/ha)		Gross returns (₹/ha)	Net returns (₹/ha)	Cost of cultivation (₹/ha)	Benefit: cost ratio
	Grain Pooled	Straw Pooled	Pooled	Pooled	Pooled	Pooled
1.	3.45	5.89	66,821	42,430	24,391	1.74
2.	3.41	5.69	65,666	41,275	24,391	1.69
3.	3.82	6.33	73,346	48,705	24,641	1.98
4.	3.94	6.55	75,731	51,390	24,341	2.11
5.	3.80	6.41	73,370	48,356	25,014	1.93
6.	3.63	6.19	70,307	45,293	25,014	1.81
7.	4.46	6.89	84,217	58,380	25,837	2.26
8.	4.61	7.13	87,090	62126	24,964	2.49
9.	4.00	6.64	76,927	51,340	25,587	2.01
10.	3.82	6.42	73,700	48,113	25,587	1.88
11.	4.69	7.14	88,185	62,348	25,837	2.41
12.	4.84	7.39	91,155	65,618	25,537	2.57
13.	3.77	6.92	74,474	45,084	29,390.5	1.53
14.	3.59	6.69	71,147	41,757	29,390.5	1.42
15.	5.22	7.43	96,627	66,986	29,640.5	2.26
16.	5.28	7.70	98,275	68,935	29,340.5	2.35
17.	4.33	7.43	83,917	53,903	30,014	1.80
18.	4.11	7.18	80,112	50,098	30,014	1.67
19.	5.86	7.98	107,396	77,132	30,264	2.55
20.	5.97	8.27	109,894	79,930	29,964	2.67
21.	4.50	7.50	86,559	55,972	30,587	1.83
22.	4.27	7.25	82,604	52,017	30,587	1.70
23.	5.94	8.06	108,772	77,935	30,837	2.53
24.	6.10	8.35	111,913	81,376	30,537	2.66

improvement in various components can be ascribed not only to adequate supply of assimilates/nutrients but also to their pivotal role in increasing physico-chemical and biological properties of soil, thereby, enhancing root growth and synthesis of cytokinnins. The results of present investigation indicate positive response of various yield components to fertility levels. Our finding support results of Sepat *et al*., 2010; Chesti *et al.,* 2013, Shantveerayya *et al.,* 2017.

The higher grain yield realized with addition of 125%/ 100% RDF + 5 t FYM/ha could be ascribed to its profound influence on vegetative and reproductive growth of crop and positive interrelationship between grain yield and yield components, *viz.* effective tillers, ear length, test weight, grains/ear and grain weight/ear. This clearly indicate that grain yield is dependent on several component which are interrelated with each other. Hence marked increase in grain yield with 125% RDF + 5 t FYM/ha fertilization seems to be owing to better achievement of crop genetic potential for vegetative and reproductive growth. The present results are in close agreement with the findings of Meena *et al.* (2012); Jat (2013) and Singh *et al.* (2013).

The significant increase in straw yield owing to 125% RDF + 5 t FYM/ha could be ascribed to their influence on dry-matter production at successive stages by virtue of increased photosynthetic efficiency. While indirect influence seems to be due to increase in plant height and number of tillers. The higher nutrient uptake with adequate fertilization seems to be another reason for observed improvement in straw yield. The profound influence of NPK + FYM on biological yield seems to be on account of its significant effect on vegetative (straw) growth as well as reproductive development (grain). Our results corroborate findings of Rai *et al.* (2013) and Prasad *et al*. (2019).

Liquid bio-inoculants

The inoculation of barley seed with liquid bio-fertilizer consisting of combinations of *Azotobacter* + *Azospirillum* + phosphates solubilizer + PGPR resulted in the highest grain, straw and biological yields, being at par with inoculation of *Azotobacter* + PSB and both these treatments significantly enhanced the grain, straw and biological yields over inoculation of *Azotobacter* and PSB alone during both years and in the pooled analysis. On pooled basis, co inoculation of *Azotobacter* + *Azospirillum* + phosphates solubilizer + PGPR (5.12 t/ha) and *Azotobacter* + PSB (4.99 t/ha) significantly improved the grain yield by 28.96, 25.70 and 34.73, 31.32% respectively, over single inoculation of *Azotobacter* and PSB. Further results indicated that both the combinations of liquid bio-inoculants *Azotobacter* + *Azospirillum* + phosphates solubilizer + PGPR and *Azotobacter* + PSB were equally efficient in improving productivity. Inoculation of barley seed with liquid bio-inoculant consisting combination of *Azotobacter* + *Azospirillum* + phosphates solubilizer + PGPR recorded the maximum net returns (67,906) and benefit: cost (B: C) ratio of 2.44, closely followed by seed inoculation with liquid bio inoculant *Azotobacter* + PSB with net returns (65,006) and B: C ratio of 2.31, being significantly higher than inoculation with *Azotobacter* and PSB alone.

It is an established fact that, availability of assimilates (source) and nutrients together with storage organs (sink) exert an important regulative function on complex process of barley yield formulation. It is believed that *Azotobacter* + *Azospirillum* + phosphates solubilizer + PGPR produce phytohormones, antibacterial and antifungal compound which stimulate root-system and changes in root-morphology which in turn effect the assimilates of nutrients thus influence on development of reproductive structure. The marked increase in various yield components with the inoculation of *Azotobacter* + *Azospirillum* + phosphates solubilizer + PGPR can be ascribed not only to adequate supply of assimilates/nutrients but also to their pivotal role in improving physical, chemical and biological properties of soil thereby enhancing root growth. The significant increase in grain yield with inoculation with liquid bio-inoculants could be ascribed to their positive influence on maintaining source-sink relationship which is clearly evident from improvement in dry-matter production along with its efficiency (Crop Growth Rate) and sink components. The positive interrelationship between grain yield and Crop Growth Rate between various crop duration as well as components also represented that marked increase in grain yield with inoculation with bio inoculants was on account of their proportional influence on both source as well as sink component of crop. The results of investigation corroborate findings of Yadav *et al*. (2011), Thalooth *et al*. (2012); Kumar *et al*. (2013); Neelam *et al*. (2018), Choudhary *et al.* (2018) and Malik, (2018).

Based on results emanated from the present investigation it is concluded that integrated nutrient management in barley crop with the application of 125 % RDF (75 kg N + 37.5 kg/ha) + 5 t FYM/ha and seed inoculation with liquid biofertilizer *Azotobactor* + *Azospirillum* + Phosphates solubilizer + PGPR (5 ml/kg seed) registered maximum grain yield (6.10 t/ha) and net return 81,043 with B:C ratio of 2.25. however, this treatment was statistically at par with application of 100 % RDF (75 kg N + 37.5 kg/ha) + 5 t FYM/ha and seed inoculation with liquid biofertilizer *Azotobactor* + *Azospirillum* + Phosphates solubilizer + PGPR (5 ml/kg seed) with 5.97 t/ha and net return 79,597 with B:C ratio of 2.24. Thus it is recommended that barley crop should be fertilized with 100 % RDF + 5 t FYM/ha and seed inoculation with liquid biofertilizer *Azotobactor* + *Azospirillum* + Phosphates solubilizer + PGPR for higher

productivity and profitability.

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