Indian Journal of Agricultural Sciences **94** (6): 620–625, June 2024/Article
https://doi.org/10.56093/ijas.v94i6.133410

Growth attributes of malt barley (*Hordeum vulgare*) as influenced by fertility levels and liquid biofertilizers

SONAL ATHNERE[1]*, P C CHAPLOT[1], SURYAKANT NAGRE[2], RAJENDRA PATEL[3], SALGAR S B[4], KANGUJAM BOKADO[5], PINKY YADAV[1] and KAMAL GARG[6]

Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan 313 001, India

Received: 16 February 2023; Accepted: 16 February 2024

ABSTRACT

The experiments were conducted during winter (*rabi)* seasons of 2020–21 and 2021–22 at Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan to study the effect of fertility levels and biofertilizers on malt barley (*Hordeum vulgare* L.). Factorial randomized block design (F-RBD) was used comprising 15 treatment combinations involved 3 fertility levels, viz. 50 N + 25 P_2O_5 + 15 K_2O kg/ha; 60 N + 30 P_2O_5 + 20 K_2O kg/ha; and 70 N + 40 P_2O_5 + 25 K_2O kg/ha; alongside 5 liquid biofertilizers, viz. control; *Azotobacter*; Phosphorous solubilizing bacteria; Potassium mobilizing bacteria; and *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria. The findings indicate that applying a fertilizer combination of 70 N + 40 P_2O_5 + 25 K_2O kg/ha to malt barley crop significantly enhanced plant height at harvest (118.74 cm), dry-matter accumulation/m row at harvest (356.88 g), leaf area index (LAI) at 50 DAS (days after sowing) (1.69) and 75 DAS (2.87), number of total tillers (89.97) and growth efficiency values, substantially greater than other fertility levels. The findings demonstrated that inoculating seeds with a combination of liquid biofertilizers containing *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly improved growth parameters, viz. plant height at harvest (117.55 cm), dry-matter accumulation/m row at harvest (371.25 g), LAI at 50 DAS (1.68) and 75 DAS (2.96), number of total tillers (90.08) and growth efficiency values.

Keywords: Biofertilizers, Fertility levels, Growth attributes, Malt barley

Due to the minimal input requirements of barley (*Hordeum vulgare* L.), it thrives mainly on fragmented and unfavourable land, with its cultivation predominantly concentrated in the northern plains of India, notably in states like Rajasthan, Uttar Pradesh, and Haryana. With the typical yield of 26 q/ha, barley is grown on 610.5 thousand ha in India, producing 1600 thousand tonnes. The largest state in terms of both production and area in India is Rajasthan, followed by Uttar Pradesh. Barley was grown in Rajasthan on an area of 313 thousand ha, producing 1060 thousand tonnes at a yield of 34 q/ha (IIWBR 2020–21). The increase in consumption of whisky and alternative malt-based items in various nations has led to an increase in the utilization of two-row barley in the brewing sector (Gupta *et al.* 2010). Sufficient application of fertilizers is crucial for getting elevated yields and better quality in malt barley. Even with the management of the advised amounts of essential nutrients, there is a lack of significant improvement in yield (Jat *et al.* 2018). Nitrogen is very essential component for the progress of plant, serving as a fundamental element of chlorophyll, which is indispensable for photosynthesis. Phosphorus is vital for ATP production, DNA synthesis, and protein formation, additionally, it contributes to cell membrane structure and enzyme activation, essential for overall plant health and function. Potassium is crucial for the maintenance of cellular organisms, as it regulates cell membranes and ensures the cytoplasm maintains optimal hydration levels. On the other hand, biofertilizers fix atmospheric nitrogen, solubilize phosphate, produce phyto-hormones in soil and extract inorganic potassium from clay complex (Jatinderpal 2021). By solubilizing nutrients, it plays a very important role in improving soil fertility. Therefore, keeping this in view, an experiment was planned to find out the suitable fertility levels and combinations of biofertilizers for the growth of malt barley.

MATERIALS AND METHODS

The experiments were conducted during winter (*rabi)* seasons of 2020–21 and 2021–22 at Rajasthan College of

[1]Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan; [2]Indira Gandhi National Tribal University, Anuppur, Madhya Pradesh; [3]Krishi Vigyan Kendra, Govindnagar, Narmadapurum, Madhya Pradesh; [4]Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra; [5]Lovely Professional University, Phagwara, Punjab; [6]ICAR-Indian Agricultural Research Institute, New Delhi. *Corresponding author email: athnere73@gmail.com

Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan. Experiment was laid out in factorial randomized block design (F-RBD) comprising of 15 treatment combinations having 3 levels of fertility, viz. 50 N + 25 P_2O_5 + 15 K_2O kg/ha; 60 N + 30 P_2O_5 + 20 K_2O kg/ha; and 70 N + 40 P_2O_5 + 25 K_2O kg/ha; alongside 5 liquid biofertilizers, viz. control; *Azotobacter*; Phosphorous solubilizing bacteria; Potassium mobilizing bacteria; and *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria. The rate of biofertilizers was used @5 ml/kg seeds for inoculation, 2–3 h before seeding. The seeding was done in furrows by maintaining the depth approximately 4–5 cm, employing 100 kg seeds/ha and the distance between furrows was 20 cm. Five randomly tagged plant's height from each plant were taken from plant base to the upper end of the spikelet at 25, 50, 75 DAS (days after sowing) and at harvest. Each treatment's average plant height was calculated and expressed in cm. By taking whole plant samples from the randomly chosen one metre row length in each plot, the periodic changes in dry matter at 25, 50, 75 DAS and at harvest were noted. These samples were chopped, placed in separate perforated paper bags, dried in the sun for 2–3 days and then placed in hot air oven. Thereafter, each sample weight was noted, averaged and dry-matter accumulation (DMA) for each treatment at various phases was calculated and stated as g/m row length. By using a leaf area metre, the plant's leaf area harvested for DMA at 50 and 75 DAS was calculated. The leaf area index (LAI) was determined by the expression:

$$\text{Leaf area index} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Total land area (cm}^2\text{)}}$$

The crop growth rate and relative growth rate, were assessed at intervals of 25–50, 50–75 and 75 DAS up to the harvest. At 60 DAS, the number of tillers were recorded in 5 randomly selected rows, each measuring 1 m in length from every plot, and the average number of tillers per meter row length was calculated.

RESULTS AND DISCUSSION

Plant height

Fertility levels: Throughout the experimental duration and on a mean basis, fertilization of fertility levels didn't cause any significant influence on plant height measured at 25 DAS (Table 1). The fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha to malt barley crop attained highest plant height at 50, 75 DAS and at harvest which was significantly superior over fertilization of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha in both the study years. On pooled basis, fertilization with 70 N + 40 P_2O_5 + 25 K_2O kg/ha substantially enhanced plant height at 50, 75 DAS and at harvest by (3.67 and 7.5 cm), (5.15 and 12.3 cm) and (11.98 and 22.84 cm) over application of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha, respectively.

Liquid biofertilizers: Effect of liquid biofertilizers on plant height recorded at 25 DAS didn't cause any significant influence throughout the experimental duration and on mean basis. Thus when equated to control, application of biofertilzers *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria alone and in combination *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly

Table 1 Effect of fertility levels and biofertilizers on plant height and dry-matter accumulation at successive growth stages of malt barley

Treatment	Plant height (cm)				Dry matter accumulation (g/m row)			
	Pooled				Pooled			
	25 DAS	50 DAS	75 DAS	At harvest	25 DAS	50 DAS	75 DAS	At harvest
Fertility level								
50 N + 25 P_2O_5 + 15 K_2O kg/ha	23.57	51.89	68.76	95.90	13.78	65.87	161.05	316.45
60 N + 30 P_2O_5 + 20 K_2O kg/ha	23.60	55.72	75.91	106.76	14.04	71.77	171.23	337.21
70 N + 40 P_2O_5 + 25 K_2O kg/ha	23.77	59.39	81.06	118.74	14.49	78.27	181.86	356.88
SEm±	0.37	0.82	0.95	1.43	0.27	1.00	2.33	4.79
CD (*P*=0.05)	NS	2.30	2.67	4.03	NS	2.81	6.56	13.46
Liquid biofertilizers								
Control	23.06	49.44	68.53	97.11	13.93	64.78	154.81	302.83
Azotobacter	23.97	56.91	76.86	109.55	14.14	73.60	175.39	345.31
PSB	23.86	55.50	75.14	106.57	14.09	71.22	170.55	336.68
KMB	23.32	54.50	73.74	104.90	13.98	70.24	167.29	328.16
Azotobacter + PSB + KMB	24.00	61.98	81.92	117.55	14.37	80.00	188.85	371.25
SEm±	0.48	1.06	1.23	1.85	0.35	1.29	3.01	6.18
CD (*P*=0.05)	NS	2.97	3.45	5.20	NS	3.63	8.47	17.38

DAS, Days after sowing; PSB, Phosphorous solubilizing bacteria; KMB, Potassium mobilizing bacteria.

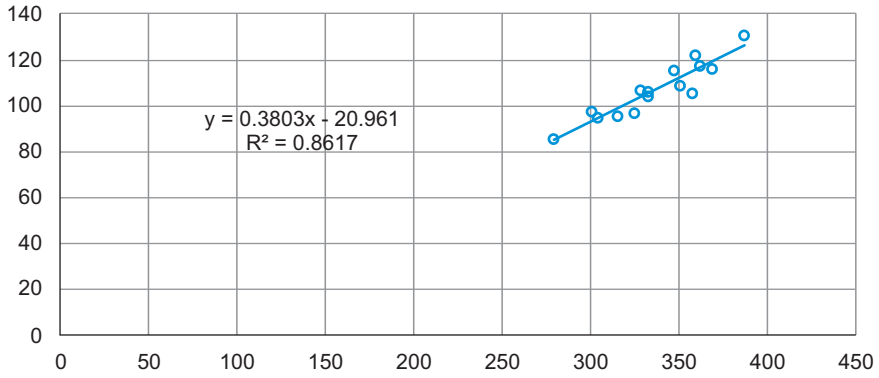

Fig. 1 Relationship between dry-matter accumulation and plant height.

enhanced mean plant height at 50, 75 DAS and at harvest by (7.47, 6.06, 5.06, 12.54 cm), (8.33, 6.61, 5.21, 13.39 cm) and (12.44, 9.46, 7.79, 20.44 cm), respectively. In case of liquid biofertilizers, combine inoculation of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria attained highest plant height at 50, 75 DAS and at harvest which was substantially greater than inoculation of liquid biofertilizers alone in both the years. On mean basis, seed treatment with *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly improved plant height at 50, 75 DAS and at harvest by (5.07, 6.48, 7.48 cm), (5.06, 6.78, 8.18 cm) and (8.01, 10.98, 12.65 cm) over single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria and Potassium mobilizing bacteria, respectively.

Dry-matter accumulation

Fertility levels: Effect of fertility levels on DMA/m row of malt barley crop was found non-significant at 25 DAS in both the years and in pooled study (Table 1). The fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha to malt barley crop accumulated maximum dry matter at 50, 75 DAS and at the time of harvesting which was substantially greater over fertilization of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha during both the years.

The pooled results show that at 50, 75 DAS and at harvest, fertilization with 70 N + 40 P_2O_5 + 25 K_2O kg/ha substantially enhanced DMA/m row (9.05 and 18.82%), (6.20 and 12.92%) (5.83 and 12.77%) over fertilization with 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha, respectively.

Liquid biofertilizers: Seed treatment with liquid biofertilizers failed to exert perceptible deviation on DMA/m row length of malt barley crop at 25 DAS in both the years of investigation and on mean basis. Data indicates that seed treatment with liquid biofertilizers alone and their combine inoculation pointedly increased DMA/m row at 50, 75 DAS and at harvest throughout the duration and on mean basis. The substantial improvement in mean DMA/m row was by 13.61, 9.94, 8.42, 23.49%; 13.29, 10.16, 8.06, 21.98%; and 14.02, 11.17, 8.36, 22.59% with the application of *Azotobacter,* Phosphorous solubilizing bacteria, Potassium mobilizing bacteria alone and in combination of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria in comparison to control, respectively. Seed inoculation with *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria accumulated maximum dry weight at 50, 75 DAS and at harvest, substantially greater than single inoculation of these in both the years. On mean basis, seed inoculation with *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly enhanced DMA/m row at 50, 75 DAS and at harvest to the extent of 8.69, 12.33, 13.89%; 7.67, 10.73, 12.89%; and 7.51, 10.26, 13.13% in comparison of single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria and Potassium mobilizing bacteria, respectively.

Leaf area index (LAI)

Fertility levels: In both the years and on average basis, LAI at 50 and 75 DAS was significantly affected by fertility levels (Table 2). The fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha to malt barley crop attained maximum LAI at

Table 2 Effect of fertility levels and biofertilizers on total tillers and leaf area index at successive growth stages of malt barley

Treatment	Total tillers at 60 DAS (per m row)	Leaf area index	
		50 DAS	75 DAS
	Pooled	Pooled	Pooled
Fertility levels			
50 N + 25 P_2O_5 + 15 K_2O kg/ha	73.57	1.32	2.41
60 N + 30 P_2O_5 + 20 K_2O kg/ha	82.17	1.54	2.66
70 N + 40 P_2O_5 + 25 K_2O kg/ha	89.97	1.69	2.87
SEm±	1.09	0.02	0.04
CD (*P*=0.05)	3.07	0.06	0.11
Liquid biofertilizers			
Control	74.31	1.36	2.35
Azotobacter	83.91	1.55	2.72
PSB	81.01	1.50	2.62
KMB	80.20	1.48	2.58
Azotobacter + PSB + KMB	90.08	1.68	2.96
SEm±	1.41	0.03	0.05
CD (*P*=0.05)	3.96	0.08	0.15

DAS, Days after sowing; PSB, Phosphorous solubilizing bacteria; KMB, Potassium mobilizing bacteria.

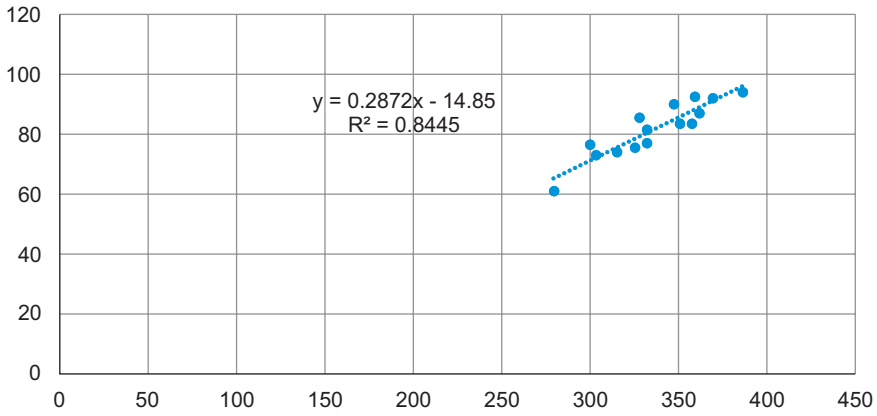

Fig. 2 Relationship between dry-matter accumulation and number of total tillers.

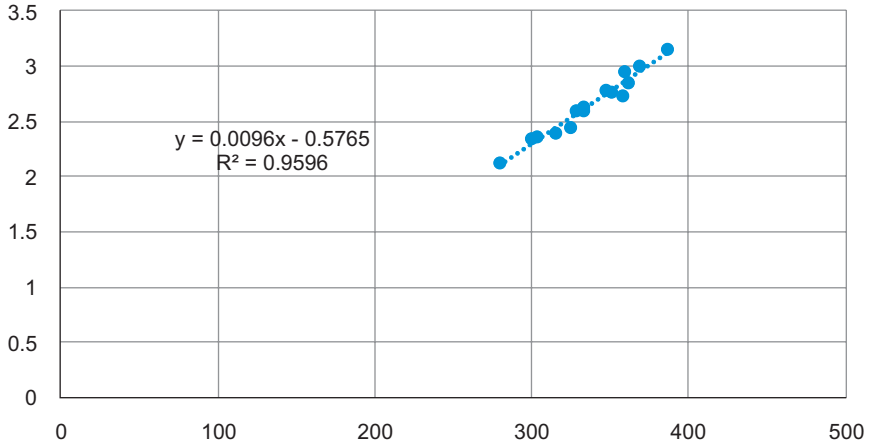

Fig. 3 Relationship between dry-matter accumulation and leaf area index.

50 and 75 DAS which was substantially greater than other fertility levels in both the years.

The mean data indicates that fertilization with 70 N + 40 P_2O_5 + 25 K_2O kg/ha substantially enhanced LAI at 50 and 75 DAS to the extent of 9.74, 28.03% and 7.89, 19.08% over fertilization of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha, respectively.

Liquid biofertilizers: Data analysis reveals that malt barley seed inoculation both individually and collectively had a significant impact on LAI at 50 and 75 DAS in both the years and on mean basis. Thus when compared to least mean LAI recorded at 50 and 75 DAS under control, single inoculation with *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria and in combination with *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly enhanced LAI at 50 and 75 DAS by 13.97, 10.29, 8.82, 23.52% and 15.74, 11.48, 9.78, 25.95%, respectively. Seed inoculation with *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria recorded highest LAI at 50 and 75 DAS, substantially greater than single inoculation with *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria in both the years. On mean basis, combine inoculation of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly enhanced LAI at 50 and 75 DAS by 8.39, 12.00, 13.51% and 8.82, 12.98, 14.73% over single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria, respectively.

Total tillers/m row length at 60 DAS

Fertility levels: The fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha to malt barley crop produced substantially greater number of tillers/m row at 60 DAS as compared to application of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha during both the years (Table 2).

On pooled basis, fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha substantially enhanced number of tillers/m row at 60 DAS by 9.49 and 22.29% over fertilization of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha, respectively.

Liquid biofertilizers: During both the years and in pooled analysis compared to control, malt barley seed treatment with *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria alone and combined application of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly increased number of tillers/m row at 60 DAS. The corresponding increases in mean number of tillers/m row length were 12.91, 9.01, 7.92 and 21.22%, respectively. Seed inoculation with biofertilizers i.e. *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria recorded higher number of tillers/m row at 60 DAS which was substantial greater than inoculation with *Azotobacter*, Phosphorous solubilizing bacteria and Potassium mobilizing bacteria alone in both the years. On mean basis, combine inoculation of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly increased number of tillers/m row by 7.35, 11.19 and 12.32% than single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria and Potassium mobilizing bacteria, respectively.

Growth efficiency

Crop growth rate

Fertility levels: The fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha recorded significant gain in crop growth rate estimated between 25–50 DAS over application of 60 kg N + 30 kg P_2O_5 + 20 kg K_2O kg/ha and 50 kg N + 25 kg P_2O_5 + 15 kg K_2O/ha during both the years but for crop growth rate estimated between 50–75 DAS and 75 DAS and at harvest, it was significantly higher over fertilization

Table 3 Effect of fertility levels and biofertilizers on crop growth rate and relative growth rate at successive crop duration of malt barley

Treatment	CGR (g/m^2/day)			RGR (g/g/day)		
	Between 25–50 DAS	Between 50–75 DAS	Between 75 DAS to harvest	Between 25–50 DAS	Between 50–75 DAS	Between 75 DAS to harvest
	Pooled			Pooled		
Fertility levels						
50 N + 25 P_2O_5 + 15 K_2O kg/ha	10.42	19.04	31.08	0.0624	0.0358	0.0270
60 N + 30 P_2O_5 + 20 K_2O kg/ha	11.55	19.89	32.94	0.0654	0.0348	0.0271
70 N + 40 P_2O_5 + 25 K_2O kg/ha	12.76	20.72	35.00	0.0676	0.0337	0.0270
SEm±	0.19	0.27	0.67	0.0007	0.0007	0.0008
CD (*P*=0.05)	0.54	0.75	1.89	0.0020	NS	NS
Liquid biofertilizers						
Control	10.17	18.01	29.60	0.0613	0.0348	0.0269
Azotobacter	11.89	20.36	33.57	0.0660	0.0349	0.0271
PSB	11.43	19.87	33.22	0.0647	0.0351	0.0272
KMB	11.25	19.41	32.17	0.0647	0.0347	0.0270
Azotobacter + PSB + KMB	13.13	21.77	36.48	0.0687	0.0344	0.0270
SEm±	0.25	0.35	0.87	0.0009	0.0010	0.0011
CD (*P*=0.05)	0.70	0.97	2.45	0.0025	NS	NS

DAS, Days after sowing; PSB, Phosphorous solubilizing bacteria; KMB, Potassium mobilizing bacteria.

of 50 N + 25 P_2O_5 + 15 K_2O kg/ha but found at par with fertilization of 60 N + 30 P_2O_5 + 20 K_2O kg/ha during both the years (Table 3).

On mean basis, fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha substantially enhanced crop growth rate between 25–50 DAS, 50–75 DAS and 75 DAS and at harvest by 10.47, 22.45%; 4.17, 8.82%; and 6.25, 12.61% over application of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha, respectively.

Liquid biofertilizers: The average data suggests that in comparison to the control inoculation with *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria alone and in combination *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly enhanced crop growth rate between 25–50 DAS, 50–75 DAS and 75 DAS at harvest by 16.91, 12.38, 10.61, 29.10%; 13.04, 10.32, 7.77, 20.87%; and 13.41, 12.22, 8.68, 23.24%, respectively. Among liquid biofertilizers, conjoint inoculation of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria recorded highest crop growth rate between 25–50 DAS, 50–75 DAS and 75 DAS and at harvest which was substantially greater than single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria during both the years. On mean basis, seed treatment with *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly improved crop growth rate between 25–50 DAS, 50–75 DAS and 75 DAS harvest to the tune of 10.42, 14.87, 16.71%; 6.92, 9.56, 12.15%; and 8.66, 9.81, 13.39% than single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria and Potassium mobilizing bacteria, respectively.

Relative growth rate

Fertility levels: The fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha noted maximum relative growth rate between 25–50 DAS which was significantly higher over application of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha during both the years except during 2021–22, the magnitude of difference between fertility levels 70 N + 40 P_2O_5 + 25 K_2O kg/ha and 60 N + 30 P_2O_5 + 20 K_2O kg/ha was not significant (Table 3).

On pooled basis, fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha substantially enhanced relative growth rate between 25–50 DAS by 3.36 and 8.33% over fertilization of 60 N + 30 P_2O_5 + 20 K_2O kg/ha and 50 N + 25 P_2O_5 + 15 K_2O kg/ha, respectively. Increasing fertility levels didn't cause substantial variation on relative growth rate measured between 50–75 DAS and 75 DAS and at harvest in both the years of study and on mean basis.

Liquid biofertilizers: Seed treatment with *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria separately and in combination of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly improved relative growth rate estimated between 25–50 DAS than control in both the study years and on mean basis. The corresponding improvement in mean relative growth rate between 25–50 was 7.66, 5.54, 5.53 and 12.07%. Conjoint inoculation of biofertilizers *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria recorded highest relative growth rate between

25–50 DAS which was substantially higher than the single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria and Potassium mobilizing bacteria in both the years. On mean basis, co inoculation of *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria significantly enhanced relative growth rate between 25–50 DAS to the tune of 4.09, 6.18 and 6.17% over single inoculation of *Azotobacter*, Phosphorous solubilizing bacteria, Potassium mobilizing bacteria, respectively.

Malt barley seed inoculated with liquid biofertilizers failed to record significant influence on relative growth rate measured between 50–75 DAS and 75 DAS and at harvest.

In general, sufficient fertilization contributes to enhanced crop growth by playing a crucial role in altering the soil and plant environment, facilitating the proper maintenance of biological and metabolic mechanisms in the plant. N, P and K are thought to be the three most crucial mineral nutrients for maximizing the crop's genetic potential for growth and development. Nitrogen is directly involved in formation of protein, chloroplast and humic constituents of the plant structure. Besides these, it also involves in formation and translocation of plant hormones responsible for growth and development of plant (Michael and Beringer 1980). Further, phosphorus fertilization also enhances several metabolic and biochemical processes in the plant system. It plays a crucial role in plants by facilitating energy transfer and storage in the form of ATP through a process known as phosphorylation, which is essential for plant metabolism (Nega *et al.* 2015). Whereas, K activates various enzymes, increase protein, carbohydrate and fat concentration, developing resistances against drought, frost, lodging, insects and disease incidents. The increase in cropping intensity and exhaustive production system has caused a drastic depletion of soil potassium and other nutrients (Malghani *et al.* 2010).

Data showed that fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha substantially enhanced their concentration in grain and straw. Similarly, when the crop is ready to harvest, it shows that getting enough nutrients from the early growth stage is important. This is because during the later stage, many of the nutrients are moved from the plant's growing parts to where the plant is producing fruits or seeds. Hence, this hypothesis is well justified that maximum availability of nutrient to the plants under fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha is because of their greater accumulation in soil and their better uptake through roots and then, translocation within plant system. Improvements in the nutritional status of plants may have facilitated the synthesis of growth-promoting substances such as amino acids and proteins. This is believed to induce heightened meristematic activity, increased cellular division and expansion, as well as elongation, ultimately leading to an augmentation in plant height. Likewise, significant improvement in tiller production is due to higher growth of lateral buds because of maximum availability of nutrients and assimilates (Jatindrer 2021). Along with protein synthesis, nitrogen increases the chlorophyll formation. The rise in leaf area index with the fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha may be ascribed to expanded leaf area as a result of increased cell division and enlargement by higher NPK nutrition. The correlation studies also substantiated positive interrelationship between DMA/m row with plant height ($r = 0.928^{**}$), tillers/m row ($r = 0.919^{**}$) and LAI ($r = 0.980^{**}$) (Fig. 1, 2 and 3). Further regression studies indicate strong dependence of dry matter/m row on aforesaid parameters as each unit rise in these improved dry matter by 0.38, 0.28 and 0.009 g/m row, respectively. The beneficial effect of adequate fertilization on plant height, total tillers and DMA in malt barley was also noted by Prakash *et al.* (2015), Bhawana *et al.* (2018), Jat *et al.* (2018).

Drawing from the study findings, it is proposed that a combined fertilization of 70 N + 40 P_2O_5 + 25 K_2O kg/ha along with seed treatment with *Azotobacter* + Phosphorous solubilizing bacteria + Potassium mobilizing bacteria demonstrated as the optimal practice for enhancing the growth attributing characters and improve productivity and profitability of malt barley crop.

REFERENCES

Bhawana S, Yadav R S, Verma J K and Bijarnia A L. 2018. Effect of different nutrient management treatments on growth and yield of wheat (*Triticum aestivum* L.) pearl millet (*Pennisetum glaucum* L.) cropping system. *International Journal of Agricultural Sciences* **10**(12): 6381–384.

Gupta M, Abu-Ghannam N and Gallaghar E. 2010. Barley for brewing: Characteristic changes during malting, brewing and applications of its by-products. *Comprehensive Reviews in Food Science and Food Safety* **9**: 318–28.

IIWBR. 2020–21. Progress Report, All India coordinated wheat and barley improvement project. Indian Institute of Wheat and Barley Research, Karnal, Haryana.

Jatinderpal S M. 2021. 'Effect of nitrogen levels and bio-fertilizers on growth and productivity of malt barley (*Hordeum vulgare* L.)'. MSc Thesis, Punjab Agriculture University, Ludhiana, Punjab.

Jat M K, Purohit H S, Choudhary S K, Singh B and Dadarwa R S. 2018. Influence of integrated nutrient management on yield and nutrient uptake in sorghum-barley cropping sequence. *International Journal of Chemical Studies* **6**(3): 634–38.

Malghani A L, Malik A U, Sattarb A, Hussaina G and Hussain J. 2010. Response of growth and yield of wheat to NPK. *Science International* **24**: 185–89.

Michael G and Beringer. 1980. The role of hormones in yield formation: Physical aspect of crop productivity. *International Potash Institute Switzerland* **7**: 85–116.

Nega Y, Abraha A and Samuel G. 2015. Interaction effects of inorganic N-fertilizer and seed rates on yield and quality traits of malt barley varieties in the highland of Tigray, North Ethiopia. *Journal of Natural Sciences Research* **5**(13): 157–64.

Prakash J, Siddiqui M Z, Dwivedi A, Thaneshwar B P and Singh A. 2015. Effect of irrigation and fertility balance on performance and production economics of barley (*Hordeum vulgare* L.). *International Journal of Agriculture Sciences* **7**(13): 817–21.