Energy

Considering the energy coefficients earlier worked out for various mechanical operation (Nadre, 2005), the energy input and energy output were calculated for each level of mechanization and accordingly the energy output : input ratio was determined. The data are presented in Table 6.

Under partial mechanization, the highest energy input was observed followed by in complete mechanization treatment (Table 6). Under traditional method of cultivation, less energy input was observed. However, under complete mechanization treatment, highest energy output was observed followed by under partial mechanization and traditional method of cultivation. The energy output: input ratio was the highest under complete mechanization followed by under partial mechanization. Yousif *et al.* (2012) studied the performance of combine harvester and thresher and found similar energy contents. Nadre (2005) studied the various output: input ratio under various farm operations using various machineries and found similar type of energy output: input ratio.

Complete mechanization in soybean resulted in higher seed yield, net returns, benefit: cost ratio and rainwater-use efficiency. *In-situ* moisture-conservation practices such as BBF and ridges and furrow recorded highest seed yield, net monetary returns, benefit: cost ratio and rainwater-use efficiency as compared to traditional method of cultivation. Complete mechanization along with BBF method of sowing soybean was found to be significantly superior to all the treatment combinations with respect to seed yield, NMR and RWUE. The highest energy output: input ratio (10.2) was observed in complete mechanization with BBF method of sowing.

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Research Paper

Productivity and profitability of malt barley (*Hordeum vulgare*) varieties at different nitrogen levels under saline water irrigation

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ABSTRACT

A field experiment was conducted at Hisar, Haryana during the winter (*rabi*) seasons of 2017–18 and 2018–19, to study the growth, yield and economics of 4 varieties, viz. 'BH 902', 'BH 946', 'BH 885' and 'DWRB 101' of barley (*Hordeum vulgare* L.) at different nitrogen levels (0, 30, 60 and 90 kg/ha) under saline-water irrigation. Variety 'BH 946' recorded significantly higher dry-matter accumulation, leaf-area index, grains/spike, grain yield, gross returns, net returns and benefit: cost ratio, while variety 'DWRB 101' produced significantly higher number of effective tillers, spike length and 1,000-grain weight than 'BH 902', 'BH 946' and 'BH 885' varieties. Variety 'BH 946' gave 5.1, 7.3 and 14.7% higher grain yield and 7.2, 8.0 and 19.1% higher net returns than 'DWRB 101', 'BH 902' and 'BH 885' varieties, respectively. Nitrogen levels significantly increased growth and yield attributes over the control. Each increment of nitrogen dose resulted in significantly higher grain yield, straw yield, gross returns, net returns and benefit: cost ratio only up to 60 kg/ha and further increasing the dose to 90 kg N/ha did not show any significant improvement. For getting higher productivity and profitability, malt barley variety 'BH 946' with 60 kg N/ha under saline water irrigation was found most suitable.

***Key words* :** Economics, Grain yield, Malt barley, Nitrogen levels, Varieties

Barley is fourth important cereal crop after rice, wheat and pearl millet. Rajasthan, Uttar Pradesh, Haryana, Punjab and Madhya Pradesh are the major barley-growing states in India. In Haryana, it was grown on an area of 0.02 million ha with the production of 0.73 million tonnes and productivity of 3,650 kg/ha (indiastat.com, 2019). This crop is considered as poor man's crop because of its low input requirement and better adaptability to drought, salinity, alkalinity and marginal lands. Due to uncertainty of rainfall and scarcity of water, farmers of Haryana often irrigate the crops with poor-quality water and this situation is likely to become more alarming with the depleting water resources. Thus, there is need to find out the ways to use poor-quality saline water for crop production. Kumar *et al.* (2012) observed that lower salinity level (3.0 dS/m) did not significantly influence the yield and yield-attributing characters of wheat but higher salinity levels reduced the grain yield as compared to control. Hence there is need to see the performance of malt barley varieties under saline water irrigation. Keeping such emerging problems, the present study signifies the importance of using saline water for malt barley production.

The important use of barley throughout the world is as malt for manufacturing beverages and malt-enriched food products. Nitrogen is another important input that affects both yield and quality of barley. Insufficient nitrogen can reduce grain yield and quality below acceptable levels, while excess nitrogen usually enhances undesirable high protein levels. Reddy and Singh (2018) recorded significant increase in number of effective tillers/m^2, number of grains/spike and grain yield only up to 75 kg N/ha, while Kassie and Tesfaye (2019) reported significant increase in grain yield up to 92 kg N/ha but the grain protein content at this level exceeds the highest acceptable limit (11.5%) for malting. Ejigu *et al.* (2015) observed that varieties 'Holker' and 'Beka' exhibited increasing trend in grain yield with the increase in nitrogen dose up to 50 kg/ha, but grain yield was decreased in varieties 'Miscal 21' and 'EH 1293' when nitrogen was applied beyond 30 kg/ha. The research findings indicated that some varieties responded to higher nitrogen levels but others responded to lower nitro-

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gen levels. Hence there is a need to evaluate the varieties with matching nitrogen levels that give good yield. However, information on the effect of nitrogen levels on grain yield of malt barley varieties, particularly under saline water irrigation, is not available in India. Keeping these aspects in view, the present study was undertaken.

MATERIALS AND METHODS

The field experiment was conducted during the winter (*rabi*) seasons of 2017–18 and 2018–19 at Research Farm of Department of Soil Science, CCS Haryana Agricultural University, Hisar, which is situated in semi-arid, sub-tropics at (29º 8´ N, 75º 70´ E, and 215.2 m above mean sea-level). It is characterized by semi-arid and subtropical type of climate, with an average annual rainfall is 450 mm. Total rainfall of 15.9 mm and 28.6 mm and pan evaporation of 47.1 mm and 41.8 mm were received during 2017–18 and 2018–19, respectively. The soil was sandy loam in texture, with *p*H of 8.3, available nitrogen 175.0 kg/ha, phosphorus 17.0 kg/ha and potassium 320.0 kg/ha. The experiment was laid out in a split plot design by keeping 4 varieties 'BH 902', 'BH 946', 'BH 885' and 'DWRB 101' in main plots and 4 nitrogen levels (0, 30, 60 and 90 kg/ha) in subplots with 4 replications. The crop was sown on 22 November 2017 and 26 November 2018 by *pora* method at row spacing of 22 cm, using 90 kg/ha seed rate. Half dose of nitrogen as per treatment and full dose of phosphorus (P_2O_5) and potassium (K_2O) was applied at sowing in the form of urea, single superphosphate and muriate of potash fertilizers, respectively. The remaining nitrogen was top-dressed after the first irrigation as per treatment. The crop was irrigated twice during each growing season with saline water having EC_{iw} 8.0 dS/m, *p*H 7.5 and SAR of 15.2 me/litre. The soluble ions in the saline irrigated water were Na^+ 55.1, K^+ 0.36, Ca^{2+} 7.5, Mg^{2+} 18.5, CO_3^{2-} nil, HCO_3^- 1.6, Cl^- 48.2 and SO_4^{2-} 13.7 me/ litre. The crop was harvested manually on 6 April 2018 and 8 April 2019. The various biometric observations were recorded on 5 random plants from each experimental plot. Leaf area was measured with leaf-area meter at 30, 60, 90 and 120 days after sowing (DAS) and leaf-area index (LAI) was calculated as leaf area per unit ground area. Number of grains of 5 random spikes was counted from each plot at harvesting and the mean values were calculated. Weight of total produce including straw and grains from each net plot was recorded as biological yield. Produce of each net plot was threshed separately and grains thus obtained were winnowed, cleaned and weighed. Economics was calculated as per the prevailing market prices of inputs and produce during the years of experimentation. Data on yield and yield-attributing parameters were statistically analyzed by using the technique of analysis of variance (ANOVA) described by Gomez and Gomez (2010).

RESULTS AND DISCUSSION

Growth parameters

Plant height and dry-matter accumulation (DMA) varied considerably due to various varieties and application of nitrogen levels under saline water irrigation. Plant height was not significantly affected by the varieties at 30 DAS; however, significant variation was observed at the later stages of crop growth (Table 1). At 60 DAS, both 6-rowed barley varieties ('BH 902' and 'BH 946'), being at par with each other, recorded significantly taller plants than 2-rowed barley varieties 'BH 885' and 'DWRB 101'. At 90 DAS, 120 DAS and harvesting, the maximum plant height at time of harvesting was recorded by variety 'BH 902' being significantly higher than 'BH 946', 'BH 885' and 'DWRB 101'. The lowest plant height was recorded in DWRB 101 at all growth stages. The differences in plant height among the barley varieties may be attributed to their genetic makeup and environmental conditions. Varietal differences in plant height were also reported by Saha *et al.* (2018). Ejigu *et al.* (2015) reported that malt barley varieties 'Miscal 21' and 'EH 1293' attained the highest plant height as compared to variety 'Beka' and 'Holker'. Among the N levels, 90 kg N/ha recorded highest plant height at 30, 60, 90 and 120 DAS and at maturity which was statistically at par with 60 kg N/ha and significantly more in comparison to 30 kg N/ha and the control. Significant increase in the plant height with the increase in nitrogen levels may be owing to the fact that nitrogen plays an important role in cell-division and cell-elongation, thus enhancing vegetative growth of the plant. Higher uptake of nutrients was also observed under more supply of nitrogen. Reddy and Singh (2018) also reported such a favourable effect of nitrogen levels on plant height of barley.

Dry-matter accumulation (DMA) and leaf-area index (LAI) are important parameters reflecting growth and metabolic activities of the plant. At 30 DAS, variety 'BH 902' produced the maximum DMA and LAI and it was statistically similar with variety 'BH 946' and significantly better than variety 'BH 885' and 'DWRB 101' (Table 1). At 60, 90 and 120 DAS, 'BH 946' produced significantly more DMA and LAI than all the other varieties. The results showed that at 120 DAS, variety 'BH 946 produced 52.4, 97.1 and 180.8 g/m^2 higher dry-matter than 'BH 902', 'DWRB 101' and 'BH 885' respectively. Higher DMA in variety 'BH 946' was owing to more tillers/m row length and leaf-area index (LAI). It is well known fact that, genetic differences exist among different genotypes for growth and development characters. The present investigation showed that genetic potential of 6-row barley varieties resulted in taller plants than 2-row barley varieties which followed the similar trend for DMA and LAI. Terefe *et al.* (2018) observed highest DMA in barley variety HB 1963 and lowest in variety Explorer. The DMA and LAI were significantly improved with each successive dose of N up to 90 kg/ha over the control. Maximum DMA and LAI at 30, 60, 90 and 120 DAS were produced with application of 90 kg N/ha which were significantly higher than the control, 30 and 60 kg N/ha. At 120 DAS, application of 90 kg N/ha recorded 3.0, 27.1 and 28.4% higher DMA than 60 kg N/ha, 30 kg N/ha and the control respectively. Significantly higher DMA and LAI under increased the nitrogen supply may be owing to the fact that N helped in cell-division and cell-elongation leading to higher plant height, number of tillers/m row length and ultimately higher DMA and LAI were achieved.

Yield-attributing characters

Yield attributes such as effective tillers/m row length, spike length, number of grains/spike and 1,000-grain weight were significantly influenced by different varieties and nitrogen levels (Table 2). Variety 'DWRB 101' recorded the maximum effective tillers/m row length and 1,000-grain weight which was significantly higher than 'BH 885', 'BH 902' and 'BH 946'. Higher 1,000-grain

Table 1. Periodical changes in plant height, dry-matter accumulation and leaf-area index of malt barley varieties as influenced by different nitrogen levels (pooled data of 2 years)

Treatment	Plant height (cm)					Dry-matter accumulation (g/m^2)				Leaf-area index			
	30 DAS	60 DAS	90 DAS	120 DAS	At harvesting	30 DAS	60 DAS	90 DAS	120 DAS	30 DAS	60 DAS	90 DAS	120 DAS
Varieties													
'BH 902'	27.1	63.7	95.7	118.6	120.1	33.8	312.3	681.4	1,007.3	0.46	2.16	3.47	1.74
'BH 946'	26.7	62.4	92.9	111.6	113.1	33.0	332.0	724.4	1,059.7	0.45	2.17	3.53	1.78
'BH 885'	25.7	52.6	86.1	101.8	103.4	28.8	251.8	543.2	878.9	0.38	1.87	2.97	1.50
'DWRB 101'	26.3	57.6	84.5	99.6	100.9	31.1	296.4	651.4	962.6	0.41	2.02	3.27	1.61
SEm±	0.6	1.1	0.5	0.4	0.3	0.3	3.3	6.1	6.6	0.01	0.02	0.03	0.01
CD (P=0.05)	NS	3.5	1.5	1.2	1.0	0.9	9.7	18.3	19.7	0.03	0.05	0.07	0.03
Nitrogen (kg/ha)													
0 (Control)	25.0	51.3	81.2	99.0	100.7	25.7	209.9	472.1	782.1	0.36	1.41	2.49	1.23
30	26.3	58.5	89.3	107.2	109.5	30.8	307.9	670.1	975.7	0.41	2.08	3.29	1.65
60	27.1	62.7	94.0	111.9	113.1	34.3	330.9	716.7	1,058.9	0.45	2.32	3.62	1.84
90	27.6	63.8	94.8	112.7	114.2	36.1	343.9	741.6	1,091.8	0.47	2.40	3.84	1.91
SEm±	0.3	0.3	0.3	0.3	0.3	0.3	1.3	2.3	4.2	0.003	0.02	0.02	0.01
CD (P=0.05)	0.8	1.1	0.9	0.9	1.1	0.7	3.8	6.9	12.3	0.01	0.04	0.04	0.02

DAS, Days after sowing

Table 2. Effect of different nitrogen levels on yield-attributing characters, grain yield and harvest index of malt barley varieties (pooled data of 2 years)

Treatment	Effective tillers/m row length	Spike length (cm)	Grains/ spike	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Varieties								
'BH 902'	71.1	6.53	44.7	45.8	4.77	6.42	11.20	42.6
'BH 946'	75.5	6.67	45.7	45.5	5.15	6.32	11.47	44.9
'BH 885'	94.1	6.82	24.0	48.2	4.39	5.61	10.00	43.9
'DWRB 101'	97.8	6.96	25.3	48.9	4.89	5.87	10.66	45.4
SEm±	0.3	0.05	0.1	0.2	0.08	0.08	0.06	0.9
CD (P=0.05)	1.0	0.13	0.4	0.5	0.27	0.27	0.19	NS
Nitrogen (kg/ha)								
0 (Control)	79.3	6.27	31.4	45.8	3.89	5.16	9.05	43.0
30	83.8	6.65	34.4	47.2	4.87	5.96	10.83	45.0
60	86.8	6.99	36.9	47.7	5.21	6.48	11.69	44.6
90	88.6	7.02	37.0	47.7	5.24	6.63	11.86	44.2
SEm±	0.4	0.02	0.1	0.1	0.02	0.05	0.03	0.3
CD (P=0.05)	1.2	0.07	0.4	0.3	0.07	0.16	0.09	0.9

weight in 2-row barley varieties may be attributed to their bold grains. Saha *et al.* (2018) also observed that, 2-row barley variety 'DWRUB 52' produced more effective tillers than 6-row barley variety 'PL 807'. Similarly, 'DWRB 101' attained the maximum spike length (6.96 cm) which was significantly more than 'BH 902' (6.53 cm), 'BH 946' (6.67 cm) and 'BH 885' (6.82 cm). This was owing to the variation in genetic make-up of different varieties. Ejigu *et al.* (2015) observed no significant difference between varieties 'Holker' and 'Miscal 21' for spike length, while variety 'EH 1293' recorded the maximum spike length and variety 'Beka' recorded shortest spike length. Maximum number of grains/spike were produced by variety 'BH 946' which was statistically at par with 'BH 902', but showed its significant superiority to 'DWRB 101' and 'BH 885'. The reason for higher number of grains/spike in 6-row barley varieties was due to presence of 3 pairs of spikelet rows/spike as compared to only 1 pair in 2-row barley varieties. Kefale (2016) observed that, variety 'Bahat' recorded significantly more grains/spike in than 'Sabini' and 'Local' variety of malt barley. Application of 90 kg N/ha resulted in 2.0, 5.4 and 10.9% more effective tillers than 60 kg N/ha, 30 kg N/ha and the control respectively. Maximum spike length, grains/spike and 1,000-grain weight was obtained with 90 kg N/ha, being statistically similar with 60 kg N/ha but significantly higher than 30 kg N/ha and the control. Increase in number of effective tillers, spike length, number of grains/spike and 1,000-grain with the increase in N levels was attributed to the physiological role of nitrogen in enhancing plant height, DMA and LAI that led to increased source size and more translocation of photosynthates towards sink. Dubey *et al.* (2018) recorded significantly more spikelets/spike, spike length, grains/spike and test weight with each increment of nitrogen level up to 60 kg/ha over the control, whereas Terefe *et al.* (2018) found significant increase up to 54 kg N/ha. Contrary to the above findings, Ejigu *et al.* (2015) observed non-significant differences among different nitrogen levels on spike length. Variable response of nitrogen with respect to test weight was also reported by various workers. Test weight was significantly improved up to 45 kg N/ha (Reddy and Singh, 2018), up to 60 kg N/ha (Dubey *et al.*, 2018), up to 92 kg N/ha (Kassie and Tesfaye, 2019) and further increase in nitrogen application reduced the 1,000-grain weight.

Grain, straw and biological yields

Grain, straw and biological yields revealed marked variation under saline water irrigation with respect to various varieties and nitrogen levels. The maximum grain yield (5.15 t/ha) was given by variety 'BH 946' and it was statistically similar with variety 'DWRB 101' but gave significantly more than variety 'BH 902' and 'BH 885' (Table 2). Variety 'BH 946' recorded 5.1, 7.3 and 14.7% higher grain yield than 'DWRB 101', 'BH 902' and 'BH 885', respectively. The significant increase in grain yield of 'BH 946' was owing to more DMA, LAI and number of grains/spike than the other varieties. Variety 'DWRB 101' gave produced significantly higher grain yield than 'BH 885' and it was statistically similar with 'BH 902'. Increased grain yield in variety 'DWRB 101' might be owing to more effective tillers/m row length and higher 1,000-grain weight than the other varieties. The lowest yield was recorded in variety 'BH 885' during both the years of investigation. Kassie and Tesfaye (2019) and Saha *et al.* (2018 also reported varietal differences for grain yield. Maximum straw yield (6.42 t/ha) was obtained in variety 'BH 902' which was 1.7, 8.6 and 12.7% higher as compared to 'BH 946', 'DWRB 101' and 'BH 885' respectively. The results indicated that, both 6-row barley varieties 'BH 902' and 'BH 946' recorded significantly more straw and biological

Table 3. Effect of different nitrogen levels on the economics (× 10^3₹/ha) of malt barley varieties (pooled data of 2 years)

Treatment	Gross returns	Cost of cultivation	Net returns	Benefit: cost ratio
Varieties				
'BH 902'	81.8	22.0	59.8	3.72
'BH 946'	87.0	22.0	65.0	3.95
'BH 885'	74.6	22.0	52.6	3.39
'DWRB 101'	82.3	22.0	60.3	3.74
SEm±	1.3	_	1.3	0.06
CD (P=0.05)	4.1	_	4.1	0.19
Nitrogen (kg/ha)				
0 (Control)	66.5	21.4	45.1	3.11
30	82.2	21.8	60.4	3.77
60	88.1	22.2	66.0	3.97
90	88.9	22.6	66.3	3.93
SEm±	0.4	_	0.4	0.02
CD (P=0.05)	1.2	_	1.2	0.06

yields than 2- row barley varieties 'BH 885' and 'DWRB 101'. Higher straw and biological yields in 6-row barley varieties may be attributed to their genetic behaviour and better plant growth in terms of more plant height, DMA and LAI. Terefe *et al.* (2018) recorded vigorous growth in variety 'HB 1963' which resulted in higher straw yield than variety 'Explorer'. Nitrogen application resulted in significantly higher grain yield, straw yield and biological yields only up to 60 kg/ha and further enhancing nitrogen level up to 90 kg/ha did not show any significantly improvement. Results showed that nitrogen application at 30, 60 and 90 kg/ha enhanced the grain yield by 25.3, 34.0 and 34.7%, straw yield by 15.3, 25.4 and 28.4% and biological yield by19.7, 29.2 and 31.0%, respectively, over the control treatment. Improvement in grain, straw and biological yields with increased N dose was owing to better plant growth as well as yield-contributing characters as reflected from higher plant height, DMA, LAI, effective tillers/m row length, grains/spike and 1,000-grain weight. Kassie and Tesfaye (2019) reported significantly higher grain yield with each increment of nitrogen level up to 92 kg/ha. Contrary to the above findings, Terefe *et al.* (2018) observed that grain yield of malt barley significantly increased only up to 36 kg N/ha, whereas straw yield increased up to 54 kg/ha.

Harvest index

The varieties did not significantly influence the harvest index (HI); however variety 'DWRB 101' recorded numerically higher values of HI, followed by 'BH 946', 'BH 885' and 'BH 902' (Table 2). Ejigu *et al.* (2015) reported that HI was not significantly affected by various varieties. Contrary to these findings, Kefale (2016) observed significant variation among different varieties and reported that variety 'Bahat' showed significantly higher value of HI than 'Sabini' and 'Local' variety. Application of 30, 60 and 90 kg N/ha recorded statistical similar but significantly higher values of HI than the control treatment. Increase in HI with nitrogen application was because of their high grain yield production ability from the total biological yield. The interaction effect for all the parameters were found non-significant.

Economic returns

Variety 'BH 946' recorded significantly higher gross returns, net returns and benefit: cost ratio (B: C ratio) than all other varieties under saline water irrigation (Table 3). Gross returns, net returns and B : C ratio under 'BH 946' were 5.4, 6.0 and 14.3%, 7.2, 8.0 and 19.1% and 5.3, 5.8 and 14.2% higher over 'DWRB 101', 'BH 902' and 'BH 885', respectively. Higher economic returns under 'BH 946' were attributed to its higher grain and straw yield. Varieties 'DWRB 101' and 'BH 902' remained statistically at par with each other and gave significantly higher gross returns, net returns and B: C ratio as compared to variety 'BH 885'. Among different nitrogen levels, maximum gross and net returns were obtained with 90 kg N/ha which was statistically at par with 60 kg N/ha but was significantly higher than 30 kg N/ha and the control. Nitrogen application at 90 kg/ha resulted in 0.9, 7.5 and 25.2% higher gross returns and 0.5, 8.9 and 32.0% net returns than 60 kg N/ha, 30 kg N/ha and control respectively. The highest gross and net returns under 60 and 90 kg N/ha were primarily owing to higher grain and straw yield in these treatments. In terms of B: C ratio, an application of 60 kg N/ha appeared to be superior with mean B: C ratio of 3.97, which was statistically at par with 90 kg N/ha but was significantly higher than 30 kg N/ha and control. Dubey *et al.* (2018) obtained highest net returns (23,593₹/ha) and B: C (1.04) with application of 60 kg N/ha.

From the above study it can be concluded that for getting higher productivity and profitability out of 4 varieties, 'BH 946' with application of 60 kg N/ha under saline water irrigation was most suitable.

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