International Journal of Agricultural Sciences
Volume **18** | Issue 2 | June, 2022 | 847-855 ■ ISSN : 0973-130X
☞ **DOI:10.15740/HAS/IJAS/18.2/847-855**
Visit us : *www.researchjournal.co.in*

A Review

Performance of barley (*Hordeum vulgare* L.) varieties for growth, yield and yield attributes and malt quality parameters

Amandeep Kaur* **and** Ramandeep Kaur
Department of Agronomy, Lovely Professional University, Phagwara (Punjab) India
(Email: amugorsian@gmail.com, ramandeepkaur201533@gmail.com)

Abstract : Malting barley is grown as a cash crop in a number of developed and developing countries' including India and malt is the second largest use of barley. Among cereals, barley is most preferred for malt, as its husk protecting the coleoptile (acrospire) during germination process and provides aid in filtration, firm texture of grains and its amylase activity makes it unique for malt recovery. The major portion of the produce is utilized for feed and food purposes and nearly 20-25% of the produce is consumed by the malting industry. With the growing urbanization, more open economy and changing lifestyles demand for quality malt and malt products has increased in last two decades. The malt utilization for different uses has also changed in recent years, with an increase in proportion of malt being used for brewing and decrease in distillation. The selection of a suitable variety is the prime aspect of production technology. Barley is grown under different growing conditions *viz.,* irrigated or rainfed, timely or late sown, for feed, food or malt purposes and for problematic soils having salinity or sodicity. Several researchers and eminent investigators observed that the performance of barley varieties differs with respect to growth, yield and malt quality parameters under different agro climatic conditions.

Key Words : Barley varieties, Growth, Malt quality, Yield, Yield attributes

View Point Article : Kaur, Amandeep and Kaur, Ramandeep (2022). Performance of barley (*Hordeum vulgare* L.) varieties for growth, yield and yield attributes and malt quality parameters. *Internat. J. agric. Sci.*, **18** (2) : 847-855, **DOI:10.15740/HAS/IJAS/18.2/847-855.**

Article History : Received : 07.04.2022**; Accepted :** 04.04.2022

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in India. World over, barley is cultivated in 47.4 million hectares area with the production of 143.1 million tonnes and productivity of 3020 kg ha^{-1} (Anonymous, 2019a). It is fourth largest cereal crop after maize, wheat and rice in the world with a share of seven per cent of the global cereal production (Kumar *et al.*, 2014a). The leading barley producing countries are Russia, Germany, France, Ukraine and Australia. In India, it is fourth important cereal crop after rice, wheat and pearl millet. India produced 1.78 million tonnes of barley from 0.66 million hectares with the productivity of 2695 kg ha^{-1} (Anonymous, 2019b). Rajasthan, Uttar Pradesh, Haryana, Punjab and Madhya Pradesh are the major barley growing states in India. Barley was grown on an area 0.02 million hectares with the production of 0.73 million tonnes and productivity of 3650 kg ha^{-1} in Haryana (Anonymous, 2019b). The crop is considered

***Author for correspondence : (Present Address)**
University of Nebraska, Lincoln, U.S.A.

as poor man's crop because of its low input requirement and better adaptability to drought, salinity, alkalinity and marginal lands. Farmers prefer to barley where wheat cannot be grown due to certain limitations of inputs, insufficient irrigation water and environment unsuitable for other crops.

Barley is a hardy crop grown throughout the temperate, tropical and sub-tropical regions of the world. About 70 per cent of world barley is used for cattle feed, 25 per cent for malting and 5 per cent for food. The important use of barley throughout the world is as malt for manufacturing beverages and malt enriched food products. It is also extensively used in beer and whiskey production. Barley is a rich source of nutrients like protein, vitamin B, niacin, dietary minerals and dietary fibre and forms a staple food for many people in India. The dishes like *Chapati, Sattu* (in summers because of its cooling effects on human body) and *Missi roti* prepared from barley flour are still highly popular in India (Verma *et al.,* 2011). Each 100 g of barley grain comprise 10.6 g protein, 2.1g fat, 64 g carbohydrates, 50 mg calcium, 3 g crude fibres, 6 mg iron, 31 mg vitamin B_1, 0.10 mg vitamin B_2 and 50 µg folate. Barley is superior to wheat in some minerals and fibre contents and also contains water soluble fibre (beta glucans) and oil compound (tocotrinol) which are found to be effective in lowering cholesterol level of blood and improves the regulation of blood sugar.

The barley varieties generally differ in their yield potential and malt quality parameters. In India, two types of barley varieties *viz.,* 2-row and 6-row are generally cultivated and they differ genetically. It was observed that grains of two row variety are plump, uniform in size and possess other desirable characteristics for malt purposes whereas, in case of 6- row varieties kernel plumpness and uniformity in size are lacking hence generally 2- row varieties are preferred over 6- row for malt purposes. Terefe *et al.* (2018) reported that highest malt barley grain yield was recorded by variety Ibon174/03 as compared to HB-1963, Holker and Explorer, whereas highest grain protein content (12.58%) was observed in variety Holker and lowest (10.42%) in variety Explorer. Similarly, Kassie and Tesfaye (2019) reported 17.7% higher grain yield in variety Miscal-21 as compared to Holker. Variety Miscal-21 also recorded higher protein content in grain, while hectolitre weight was more in variety Holker. Ejigu *et al.* (2015) observed that varieties Holker and Beka exhibited increasing trend in grain yield of malt barley with increase in nitrogen dose upto 50 kg ha^{-1} but grain yield was decreased in varieties Miscal-21 and EH-1293 when nitrogen was applied beyond 30 kg ha^{-1}. They concluded that variety Miscal-21 responded up to 30 kg N ha^{-1} and variety Beka up to 50 kg N ha^{-1} for achieving higher grain yield of malt barley. The research findings indicated that some varieties may have very high yield potential but have poor malting characteristics, while other varieties may exhibit good malting characteristics but have poor yield potential. Similarly some varieties responded to higher nitrogen levels but other varieties responded to lower nitrogen levels. Hence, there is a need to evaluate the varieties with matching nitrogen levels that give good yield as well as malting characteristics.

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Performance of barley varieties for growth parameters :

Gontia and Khare (1992) evaluated 10 barley genotypes *viz.,* DL 85, DL 70, DL 157, RD 57, RD 137, Karan 18, Karan 16, Karan 15, Karan 4 and RS 6 and reported that LAI increased upto 75 days and decreased thereafter. Sharma *et al.* (2007) observed that barley cultivar BH 87 recorded maximum plant height which was significantly higher as compared to BH 393 and BH 75. Sardana and Zhang (2004) also reported varietal differences for plant height. Verma *et al.* (2008) compared different cultivars of barley and found that K 508 produced higher plant height and dry matter $plant^{-1}$ than varieties K 409 and K 551. Ram *et al.* (2010) reported that days taken to 75% flowering and maturity were significantly influenced by different varieties. The variety PL 807 took maximum days to 75% flowering and maturity which was significantly more than other varieties except BH 902 for 75% ear heading, while the variety RD 2035 taken less days to 75% ear heading and maturity.

Safina (2010) conducted two field experiments at Cairo to find out the best genotype to be grown under the sandy soil with salinity irrigation water of 2496-2650 ppm among nine barley genotypes. Out of these, six belonged to two row German types (*Hordeum distichon* L.) and three were Egyptian genotypes (*Hordeum vulgare* L.) *i.e.* Giza 123 (six rows), Giza 127 and Giza

128 (two rows types). The results showed that Giza 123 genotype was found superior to the other genotypes in all the growth characters except spike length. The superiority of Giza 123 genotype was due to its high ability to grow under Wadi El-Natroon condition. Ali *et al.* (2011) in an field experiment at Iran observed that three barley cultivars *viz.,* Kavir, Rayhanee and Karun varied significantly with respect to days taken from sowing to physiological maturity, plant height, grain yield and HI of barley. Khaled *et al.* (2014) observed that local genotype Ardhoui showed a high degree of tolerance to salinity in comparison to Bakistani and responded positively to applied nitrogen. They observed increased growth attributes in local genotype Ardhoui as compared to genotype Bakistani.

Ejigu *et al.* (2015) carried out an experiment at Kulumsa, Central Ethiopia to see the performance of four widely grown malt barley varieties Beka, Holker, Miscal 21 and EH 1293. They reported that varieties showed highly significant effect on plant height and spike length. The varieties Miscal 21 and EH 1293 were the tallest, as a result easily lodged at the end of growing season and their biological yield was low as compared to varieties Beka and Holker. Similarly, Musavi *et al.* (2012) observed maximum plant height and ear length in Binam cultivar whereas the highest of peduncle length and flag leaf length were achieved in Nosrat cultivar. Singh (2018) compared different varieties of barley and found that DWRUB 52 produced significantly more DMA, number of tillers, LAI, chlorophyll index and PAR interception than variety PL 807 and PL 426, however maximum plant height was observed in variety PL 807 in comparison to other varieties.

Saha *et al.* (2018) carried out an experiment at Ludhiana and reported that two-row barley variety DWRUB 52 produced more plant height and tiller numbers (89.26 cm and 332 per m^2, respectively) than six-row barley variety PL 807 at harvest and 90 DAS, respectively. Variety DWRUB 52 attained complete emergence within 12 DAS while variety PL 807 within 11 DAS. DWRUB 52 took more number of days (142) along with highest AGDD (1833 ^oC days) to attain physiological maturity as compared to variety PL 807 (139 days and 1757 ^0C days). They reported that variation in reaching different growth stages at different time is mainly due to the varietal difference as a two-rowed variety was taken against that of a six-rowed barley variety and two might hold different growth characteristics pattern.

Terefe *et al.* (2018) observed that there were significant differences among the barley genotypes for days taken to heading and physiological maturity. Variety Explorer took more number of days to heading (92.4) and physiological maturity (145 days), whereas variety Ibon174/03 took less number of days to heading (72.4) and physiological maturity (126 days). Explorer variety had shortest plant (61cm) while HB-1963 variety had the tallest plant (101cm). They reported that this variation was due to genetic differences among different barley varieties.

Performance of barley varieties for yield and yield attributes:

Barley variety Zaida produced more number of ears m^{-2} whereas barley variety Kym recorded more number of grains ear^{-1} (Garcia *et al.,* 1990). They also observed that cultivar Kym gave higher grain yield (7.6 t ha^{-1}) as compared to cultivar Zaida (7.5 t ha^{-1}). Hamachi and Yoshida (1990) evaluated five malt barley varieties *viz.,* Nirasaki Nijo, Nishino Gold, Yoshika 16, Amagi Niji and Kimiyataka to find out differences in grain weight and the husk thickness. They reported that variety Nirasaki Nijo, Nishino Gold and Yoshika 16 recorded less husk thickness as compared to Amagi Niji and Kimiyataka. Lowest 1000-grain weight was recorded in both the varieties Nirasaki Nijo and Nishino Gold while it was highest in variety Amagi Niji and Kimiyataka. Darwinkel (1991) while conducting a field experiment to see the performance of cultivars Hasso (six-row), Marinka and Flamenco (two-row) observed that cultivar Hasso recorded more number of grains ear^{-1} with few ears and moderate 1000-grain weight, while cultivar Marinka had higher number of ears with low grain number and very high 1000-grain weight. Purushotham *et al.* (1991) reported that among five cultivars *viz.* DL 36, DL 147, DL 157, DL 154 and Ratna, the cultivar DL 147 gave highest grain yield of barley. Dhama (1991) observed higher grain yield (1.81 t ha^{-1}) from barley cultivar RD 31 as compared to RD 57 (1.77 t ha^{-1}) and RD 137 (1.40 t ha^{-1}). Singh *et al.* (1993) observed non-significant differences in grain yield among four barley cultivars BH 75, BP 1407, BP 1196 and BP 769. Karwaska *et al.* (1998) at Rohtak compared the performance of four barley varieties *viz.,* C 138, BG 25, BH 75 and BH 87 on a sandy loam soil. They reported that variety BG 25 recorded significantly higher number of ear bearing shoots, grain yield ear head^{-1}, test weight and grain yield as compared to varieties C 138, BH 75 and BH 87. Saini and Thakur (1999) observed that variety Dolma recorded highest grain yield than all other varieties under study.

Sardana and Zhang (2005) from China reported superiority of variety 92-11 over Xiumei-3 for both grain and straw yield. At Ludhiana, genotype VJM-201 (two-row) gave significant higher grain yield than all other varieties, however differences among different varieties were found to be significant at Bathinda (Anonymous, 2003). Smilarly, McKenzie *et al.* (2004) observed that the interaction between cultivars and fertilizer levels was only significant at four sites out of the 32 sites; however, it was not consistent within these four sites. Sharma *et al.* (2007) observed higher effective tillers and spike length in variety BH 393 as compared to BH 75 but it was statistically at par with BH 87. They reported that variety BH 393 produced significantly higher grain yield than BH 87 and BH 75, while significantly higher straw yield was recorded by variety BH 87 as compared to BH 393 and BH 75. Alam *et al.* (2007) while conducting a field experiment at Bangladesh reported that among different cultivars, most of the characters showed their highest values in BB 1 and the lowest in Karan 10. The grain yield of varieties Karan 10 and Karan 163 was statistically similar with each other but significantly lower than BB 1 and Karan 351. Highest value of harvest index was recorded in cultivar Karan 351 and lowest in BB 1. Kumar *et al.* (2007) reported that variety BH 393 produced significantly more number of grains ear head^{-1}, 1000-grain weight, grain yield and straw yield as compared to other genotypes *viz.,* BH 331, BH 338 and BH 646.

Safina (2010) carried out two field experiments at Cairo to study the response of nine barley genotypes under sandy soil with saline irrigation water (2496-2650 ppm). He reported that the local genotype Giza 123 produced higher grain yield/fed followed by the exotic genotype No.3 and Giza 127 in decreasing order. He recommended Giza 123, Giza 127 and exotic genotype No.3 for getting higher productivity from barley under sandy soil with saline irrigation water. Ram *et al.* (2010) observed that variety PL 807 recorded maximum grain yield which was statistically similar with BH 902 and significantly higher as compared to RD 2552 and RD 2035. Sharma and Verma (2010) reported that among different barley varieties, K 551 gave highest mean grain yield irrespective of nitrogen and irrigation levels which was followed by variety DWR 28. Shafi *et al.* (2011) carried out a field experiment at Peshawar and observed that variety Sterling produced maximum number of grains spike^{-1}, 1000-grain weight and grain yield as compared to local variety of barley. Jankovic *et al*. (2011) reported that among four malting barley genotypes, NS 525 recorded significantly more grain weight in comparison to NS 519, Kristal and Premijum. There were significant differences in grain yield among different genotypes. Genotype Premijum produced highest average grain yield of malt barley, while NS 519 gave the lowest average grain yield. O'Donovan *et al.* (2011) conducted the field experiments at eight rainfed locations in western Canada to see the influence of five N doses (0, 30, 60, 90 and 120 kg ha^{-1}) on two row barley cultivars (AC Metcalfe and CDC Copeland). They reported that cultivar CDC Copeland showed advantages for higher grain yield over AC Metcalfe. Kumar *et al.* (2013) observed that barley varieties RD 2552, HBL 276, RD 2592, PL 419, Kedar, PL751, JB 58 and K 508 produced higher grain yield plot^{-1} as compared to other varieties under testing and showed high to very high mean performance for other yield components also.

Khaled *et al.* (2014) compared two genotypes *viz.,* local genotype Ardhoui and Bakistani under different nitrogen levels. They observed increased straw and grain yield in local genotype Ardhoui as compared to Bakistani. Ejigu *et al.* (2015) observed that varieties Miscal 21 and EH 1293 headed early but matured late and the inverse was true for varieties Holker and Beka. Varieties Beka, Miscal 21 and EH 1293 gave significantly higher number of tillers plant^{-1} (12.6 to 12.7 tillers plant^{-1}) than variety Holker (11.4 tillers plant^{-1}). With regard to the spike length, no significant difference was observed between Holker and Miscal 21, but variety EH 1293 recorded maximum spike length (21.8 cm) while variety Beka recorded shortest (17.4 cm) spike length. The harvest index was not significantly influenced by different varieties. Kefale (2016) carried out a field experiment at Ethiopia to study the effect of different varieties on grain yield of malt barley. Variety Bahat produced significantly more number of effective tillers m^{-2}, 1000-grain weight, number of grains spike^{-1}, grain yield and harvest index as compared to variety Sabini and Local. On the other hand, the Local variety recorded higher plant height, spike length and straw yield than variety Sabini and Bahat. Variation in grain yield of malt barley in response to varietal differences have been also reported by McKenzie *et al.* (2005), O'Donovan *et al.* (2015) and Vahamidis *et al.* (2017). Singh (2018) from Ludhiana reported that DWRUB 52 recorded significantly higher number of effective tillers, spike length, spike weight, number of grains spike^{-1}, 1000-grain weight, grain yield, straw yield and biological yield as compared to variety PL 807 and PL 426, however harvest index was statistically similar under DWRUB 52 and PL 807 whereas variety PL 426 recorded significantly lower harvest index than both the varieties.

Terefe *et al.* (2018) conducted an experiment at Ethiopia to see the performance of four malt barley varieties (Holker, Ibon174/03, HB 1963, and Explorer) on grain yield of barley. They reported that among different varieties, maximum average grain yield was produced by variety Ibon174/03 (5657 kg ha^{-1}) which was followed by variety HB 1963 (5443 kg ha^{-1}) and both these varieties gave significantly higher grain yield as compared to Holker (4361 kg ha^{-1}) and Explorer (3500 kg ha^{-1}). However, highest straw yield was recorded in variety HB 1963 and lowest in variety Explorer. Saha *et al.* (2018) found that two-rowed barley variety DWRUB 52 recorded significantly higher grain yield as compared to six-rowed barley variety PL 807. Heat use efficiencies for both the varieties were found significantly different throughout the crop period and variety DWRUB 52 recorded both straw and grain HUE maximum (0.63 and 0.26 g^{-1} m^{-2} ^{o}C day^{-1}) as compared to PL 807. The value of heat use efficiency was more for DWRUB 52 than that of PL 807 because of higher amount dry matter production under DWRUB 52. Heat use efficiency reflected positive linear relationship with different growth components and economic yield of crop. Kassie and Tesfaye (2019) conducted field experiments at Ethiopia to evaluate the effect of different nitrogen levels, varieties and growing seasons on the grain yield of malt barley. The results showed that variety Miscal 21 recorded higher 1000-kernel weight, grain yield and straw yield as compared to variety Holker. Variety Miscal 21 produced 515.3 kg ha^{-1} (+17.7%) more grain yield than Holker.

Performance of barley varieties for grain and malt quality:

Generally two types of barley varieties *viz.,* 2-row and 6-row are being cultivated. Two row varieties possess uniform size of grains, plumpness and other desirable characteristics such as protein content, high diastatic power and γ-amylase activity for malt purposes whereas in six row varieties kernel plumpness and uniformity in size of grains is lacking. Generally 2- row varieties are considered better for malt purposes as compared to 6-row varieties. Kernel protein content (Therrin *et al.,* 1994) and diastatic power (Eagles *et al.,* 1995) varied with different cultivars of barley. Therrein *et al.* (1994) reported that there were large differences among cultivars for malt extract and observed a significant negative correlation between diastatic power and malt extract. Kumar *et al.* (2014b) reported that now approximately 30% malt is used for energy drinks, pharmaceuticals and confectioneries, 8% for whiskies and the balance (around 60-62 %) is used by breweries. In India, barley is now becoming more and more important as commercial crop for industrial raw materials for malting and brewing. Ram and Verma (2002) studied the β-glucan content in 100 barley lines grown at two locations. They observed non-significant effect on β-glucan content in different barley lines. The β-glucan content varied from 2.9 to 7.1 % at Karnal location.

A study conducted for a period of three years under All India Co-ordinated trials showed the superiority of variety DWR 28 (first indigenously developed two row malt barley variety) over check BCU 73 in yield as well as in malt quality parameters (Anonymous, 2004). Verma *et al.* (2004) reported that two row varieties with more than 45 g 1000-grain weight, 9 to 11 per cent kernel protein content, 80 per cent malt extract and 80 to 120^{0}L diastatic power, as well as six row varieties with more than 42 g 1000-grain weight, 9 to 11.5 per cent kernel protein content, 78 per cent malt extract and 90- 130^{0}L diastatic power have been found to be more suitable for malt purpose. Plump kernels with high proportion of starch content and low to medium protein are preferred for preparation of good quality malt. Emebiri and Moody (2004) observed significant variation in grain nitrogen concentration with respect to different genotypes. Similar findings were also reported by Bertholdsson (1999) and Weston *et al.* (1993). Singh (2005) reported that grain hardness, husk content and protein content were significantly higher in six-row variety PL 172 as compared to two-row variety VJM 201, while the later variety showed significantly higher kernel plumpness, test weight and starch content. Rashid *et al.* (2007) also reported that 1000-grain weight varied with different genotypes of barely. Sardana and Zhang (2005) observed the superiority of variety 92-11 over Xiumei-3 for malt quality parameters such as low β-glucan and high β-amylase activity which may be attributed to different genetic makeup of both the varieties. Kumar *et al.* (2007) reported that barley cultivar BH 393 exhibited significantly higher protein content in grain than all other genotypes *viz.,* BH 331, BH 338 and BH 646. Lowest protein content was recorded in genotype BH 646. McKenzie *et al.* (2004) also observed that the protein concentration in grains varied with different cultivars of barley.

Safina (2010) studied the quality parameters of nine barley genotypes under different nitrogen levels on a sandy soil with salinity irrigation water of 2496-2650 ppm. He observed highest total ash (2.36%) in genotypes No.4, moisture content (10.60%) in genotypes No.1, total fat (2.59%) in Giza 128, crude protein content (15.02%) in genotypes No.2, crude fibers (2.26 %) in Giza 128 and total carbohydrates (68.80%) in genotypes No.4. Shafi *et al.* (2011) observed highest nitrogen content in plant and grain in local variety as compared to variety Sterling at Peshawar. Kaur and Singh (2011) reported that variety VJM 201 produced significantly higher malt recovery (85.7%) as compared to DWRUB 52 (84.1%), whereas variety DWRUB 52 recorded higher malt yield due to higher grain yield than VJM 201. O'Donovan *et al.* (2011) reported that cultivar CDC Copeland recorded lower protein content and more uniform kernels as compared to cultivar AC Metcalfe at Canada. Jankovic *et al*. (2011) reported that among four malt barley varieties (Kristal, Premijum, NS-519 and NS-525), highest protein content in grain (13.09%) was observed in NS-525 which was followed by NS-519 (12.81%) and Kristal (11.65%). Variety Premijum recorded lower protein content (11.07%) in comparison to all other varieties. Kumar *et al.* (2012) observed that beta glucan and protein content varied with different genotypes. They identified several genotypes for high and low beta glucan content and protein content. Variation in grain protein content of malting barley due to various genotypes was also found by McKenzie *et al.* (2005), Smith *et al.* (2012) and Carr *et al.* (2014).

Kumar *et al.* (2014a) carried out an experiment at Karnal (Haryana) to see the influence of four barley varieties on grain quality. They reported that two rowed cultivars have better grain quality parameters as compared to six rowed cultivars. In two rowed type barley cultivars, DWRUB 52 was found better and in six rowed type, BH 902 was superior. They further observed that among three groups of varieties *viz.,* two rowed and six rowed, hull-less and covered and high sugar and high lysine, there were only small differences in composition of glucose, fructose, sucrose, fructans, starch, crude protein, fat, ash and total fibre between two rowed and six rowed barley, whereas the high sugar and high lysine cultivars differed substantially in composition than two rowed and six rowed barley. Kefale (2016) carried out a field experiment at Ethiopia to study the effect of different varieties on quality characters of malt barley. He observed that the variety Bahat produced higher values with respect to hectolitre weight and protein content in grains as compared to variety Sabini and Local variety. Sainju *et al.* (2015) and Kangor *et al.* (2017) also observed variation in hectolitre weight with respect to different cultivars of malt barley. Yousif and Evans (2018) reported that brewers prefer barley varieties having plumper grains with higher proportion of starch in the kernel endosperm which results in higher extract levels, as well as reduced malt protein content which is shown to have a negative correlation with extract. They further observed that malt barley varieties generally needed a moisture content of 10–12% in grains.

Singh (2018) found that highest protein yield, starch content, hectolitre weight and bold grains proportion was obtained in variety DWRUB 52, while PL 426 had the highest protein content, grain hardness and husk content. Nitrogen content in grain and straw was significantly higher in variety PL 426, while K and Zn content in grain and straw was higher in variety DWRUB 52. Nitrogen uptake in DWRUB 52 was statistically similar with PL 807 but significantly higher in comparison to PL 426, while P, K and Zn uptake was significantly higher in variety DWRUB 52. The available NPK in soil after completion of experiment was not significantly affected by various varieties. Terefe *et al.* (2018) reported that variety HB-1963 produced highest hectolitre weight (69 kg hl^{-1}) of malt barley which was due to the suitable genetic behaviour of variety HB 1963 with the environmental factors that led to an increase in photosynthesis process and accumulation of more carbohydrates in grains. The lowest hectolitre weight (65.9 kg hl^{-1}) was obtained from variety Explorer and Holker, respectively. Variety Holker recorded highest protein content in grains (12.58%) which was followed by variety Ibon174/03 and HB 1963, while lowest protein content in grains (10.42%) was observed in variety Explorer which might be due to the low N uptake by the grains.

Table 1: Performance of malt barley varieties for grain yield, straw yield and harvest index under saline water irrigation (Pooled data of two years)

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
Varieties			
BH 902	47.73	64.24	42.6
BH 946	51.51	63.18	44.9
BH 885	43.92	56.11	43.9
DWRB 101	48.89	58.71	45.4
S.E. ±	0.72	0.80	0.9
C.D. (P=0.05)	2.65	2.69	NS

Source: Kaur (2020) NS= Non-significant

Bera *et al.* (2018) observed grain protein content in the range of 9.80-13.17% among different varieties of malt barley. Maximum grain protein content was recorded in variety DWRB 92 which was followed by DWRB 101, DWRB 91, DWRB 73 and DWRUB 52. Similarly, DWRB 92 had the highest value of diastatic power, while DWRB 101 showed lowest diastatic power among all varieties. The highest value of γ-amylase activity in malted grains was observed in variety DWRB 91 and the lowest in DWRB 92. After malting, the γ-amylase enzyme activities decreased in all the cultivars. Kassie and Tesfaye (2019) carried out field experiments on different varieties of malt barley at Ethiopia and reported that grain protein content and kernel plumpness were greater in variety Miscal-21, while hectolitre weight was greater in variety Holker. They observed that variety Miscal-21 recorded higher nitrogen concentration in grains, while variety Holker recorded greater nitrogen concentration in straw. Kaur (2020) reported that malt barley BH 946 recorded highest grain yield of 51.51 q ha^{-1}, which was 5.1, 7.3 and 14.7% higher as compared to DWRB 101, BH 902 and BH 885, respectively. However maximum straw yield was observed by variety BH 902 and harvest index by variety DWRB 101.

So, it may be concluded that the performance of barley varieties differs with respect to growth, yield and malt quality parameters under different agro climatic conditions.

REFERENCES

Alam, M. Z., Haider, S. A. and Unil, N. K. (2007). Yield and yield components of barley in relation to sowing times. *J. Biol. Sci.,* **15**: 139-145.

Ali, S. Hesam, S. M. and Lila, N. (2011). Determination of the suitable planting date and plant density for different cultivars of barley (*Hordeum vulgare* L.) in Fars. *Afr. J. Plant Sci.,* **5**: 284-286.

Anonymous (2003). Annual progress report : *Wheat, Barley and Triticale Improvement Work, Wheat Section*. Deptt of Plant Breeding, Genetics and Biotechnology, Punjab Agricultural University, Ludhiana, Punjab (India) .

Bera, S., Sabikhi, L. and Singh, A. K. (2018). Assessment of malting characteristics of different Indian barley cultivars. *J. Food Sci. Technol*., **55**: 704-711.

Bertholdsson, N. O. (1999). Characterization of malting barley cultivars with more or less stable grain protein content under varying environmental conditions. *Eur. J. Agron.,* **10**: 1-8.

Carr, P. M., Horsley, R. D., Martin, G. B. and Hochhalter, M. R. (2014). Malt barley cultivar ranking under long-term tillage systems in a semi-arid region. *Agron. J.,* **106**: 2067-2074.

Darwinkel, A. (1991). Growing winter barley for yield and quality. *Versleg-proefstatiuon voor de Akkerbouw en de Groenteteelt in de Vollegrond, Lelystad.* **131**: 55 (Original not seen. Abstr in Field Crop Abstracts, **46**: Entry No. 7262, 1993).

Dhama, A. (1991). Response of barley varieties to nitrogen under rainfed conditions. *Indian J. Agron.,* **36**: 263-264.

Eagles, H. A., Bedggood, A. G., Panoozo, J. F. and Martin, P. J. (1995). Cultivar and environmental effects on malting quality in barley. *Aust. J. Agric. Res.,* **46**: 831-844.

Ejigu, D., Tana, T. and Eticha, F. (2015). Effect of nitrogen fertilizer levels on yield components and grain yield of malt barley (*Hordeum vulgare* L.) varieties at Kulumsa, Central Ethiopia. *J. Crop Sci. & Tech.,* **4** : 11-21.

Emebiri, L. C. and Moody, D. B. (2004). Potential of low protein genotypes for nitrogen management in malting barley production. *J. Agric. Sci.,* **142**: 319-325.

Garcia del moral, L. F., Ramos, J. M., Garcia del moral, M. B., Roca De Tagore, F. and Molina Cana, J. N. (1990). Effects of genotypes and N fertilization on grain yield of barley in two contrasting environments of southern Spain. *Agricultural Mediterranea*., 303-309.

Gontia, A. S. and Khare, A. K. (1992). Optimum LAI of barley genotypes under various planting pattern. *Adv. Plant Sci.,* **5**: 43-53.

Jankovic, S., Glamoclija, D., Maletic, R., Rakic, S., Hristov, N. and Ikanovic, J. (2011). Effects of nitrogen fertilization on yield and grain quality in malting barley. *Af. J. Biotech.,* **10**: 19534-19541.

Kangor, T., Pille, S., Ylle, T., Ilmar, T. and Mati, K. (2017). Malting barley diseases, yield and quality-Response to using various agro-technology regimes. *Proc. Latvian Acad. Sci.,* **71**: 57-62.

Karwaska, R. S., Gupta, S. N. and Kadian, R. S. (1998). Response of barley varieties to nitrogen under rain fed conditions of Rohtak. *Crop Res.,* **15**: 31-33.

Kassie, M. and Tesfaye, K. (2019). Malting barley grain quality and yield response to nitrogen fertilization in the Arsi highlands of Ethiopia. *J. Crop Sci. Biotech.,* **22**: 225- 234.

Kaur, Amandeep (2020). *Performance of barley (Hordeum vulgare L.) varieties for grain yield and malt quality at various nitrogen levels under saline water irrigation.* Ph. D. Dissertation, Chaudhary Charan Singh, Haryana Agricultural University, Hisar, India.

Kaur, K. and Singh, H. (2011). Effect of levels and time of nitrogen application on grain and malt quality characteristics of barley varieties. *Environ. & Ecol.,* **29**: 542-545.

Kefale, B. G. D. (2016). Effect of nitrogen fertilizer level on grain yield and quality of malt barley (*Hordeum vulgare* L.) varieties in Malga Woreda, Southern Ethiopia. *Food Sci. & Quality Manage.,* **52**: 8-16.

Khaled, A. B., Hayek, T., Mansour, E. and Ferchichi, A. (2014). Comparing the interactive effects of NPK fertilization and saline water on two genotypes of barley (*Hordeum vulgare* L.) grown in southern of Tunisia. *Int. J. Curr. Microbiol. Appl. Sci.,* **3**: 711-721.

Kumar, D., Dey, B. R., Mian, M. J. A. and Hoque, M. A. (2013). Mitigation of adverse effect of salt stress on maize (*Zea mays* L.) through organic amendments. *Int. J. Appl. Sci. Biotech.,* **1**: 233-239.

Kumar, D., Narwal, S., Verma, R. P. S., Kharab, A. S., Kumar, V. and Sharma, I. (2012). Genotypic variability in â-glucan and crude protein contents in barley genotypes. *J. Wheat Res.,* **4**: 61-68.

Kumar, D., Narwal, S., Verma, R. P. S., Kumar, V., Kharab, A. S. and Sharma, I. (2014a). Performance of barley varieties for malting quality parameters in north western plains of India. *J. Wheat Res.,* **6**: 132-137.

Kumar, V., Khippal, A., Singh, J., Selvakumar, R., Malik, R., Kumar, D., Kharub, A. S., Verma, R. P. S. and Sharma, I. (2014b). Barley research in India: Retrospect and Prospects. *J. Wheat Res.,* **6** : 1-20.

Kumar, V., Rathee, S. S. and Yadav, A. (2007). Response of barley genotypes to varying levels of nitrogen and phosphorus. *Haryana J. Agron.,* **23**: 14-17.

McKenzie, R. H., Middleton, A. B. and Bermer, E. (2005). Fertilization and seeding rate for malting barley yield and quality in southern Alberta. *Can. J. Plant Sci*., **85**: 603-614.

McKenzie, R. H., Middleton, A. B., DeMulder, J. and Bermer, E. (2004). Fertilizer response of barley grain in southern and central Alberta. *Can. J. Soil Sci.,* **84**: 513-523.

Musavi, M., Soleymani, A. and Shams, M. (2012). Effect of cultivars and nitrogen on growth and morphological traits of barley in Isfahan Region. *Inter. J. Agric. Crop Sci*., **22**: 1641-1643.

O'Donovan, J. T., Turkington, T. K., Edney, M. J., Clayton G. W., McKenzie, R. H., Juskiw, P. E., Lafond, G. P., Grant, C. A., Brandt, S., Harker, K. N., Johnson, E. N. and May, W. E. (2011). Seeding rate, nitrogen rate and cultivar effects on malting barley production. *Agron. J.,* **103**: 709-716.

O'Donovan, J. T., Kabeta, Y. A., Grant, C., MacLeod, A. L., Edney, M., Izydorczyk, M. and Chapman, W. (2015). Relative responses of new malting barley cultivars to increasing nitrogen rates in western Canada. *Can. J. Plant Sci.,* **95:** 424-432.

Purushotham, S., Manjunata, M. and Babu, M. S. G. (1991). Performance of barley varieties for fodder cum-grain purposes. *Current Res. Univ. Agric. Sci.,* **20**: 33-34.

Ram, H., Singh, B. and Sharma, A. (2010). Effect of time of sowing on the field performance of barley (*Hordeum vulgare*) in Punjab. *J. Res. Punjab Agric. Univ.,* **47** : 132-135.

Ram, S. and Verma, R. P. S. (2002). β-Glucan content and wort filtration rate of Indian barleys. *Cereal Res. Commun.,* **30**: 181-186.

Rashid, A., Khan, U. K. and Khan, D. J. (2007). Comparative effect of varieties and fertilizer levels on barley (*Hordeum vulgare* L.). *Pak. J. Soil Sci.,* **1**: 1-13.

Safina, S. A. (2010). Effect of nitrogen levels on grain yield and quality of some barley genotypes grown on sandy soil and salinity irrigation. *Egypt. J. Agron.,* **32**: 207-222.

Saha, S. K., Singh, S. P. and Kingra, P. K. (2018). Study on specified growth attributes, thermal unit requirement and its utilization efficiency in barley cultivars under varied microenvironment. *Int. J. Curr. Microbiol. App. Sci.,* **7**: 2050-2061.

Saini, J. P. and Thakur, S. R. (1999). Response of barley (*Hordeum vulgare* L.) varieties to nitrogen under dry temperature conditions. *Indian J. Agron.,* **44** : 123-125.

Sainju, U.M., Stevens, W.B., Caesar-Ton, T. and Iversen, W.M. (2015). Malt barley yield and quality affected by irrigation, tillage, crop rotation and nitrogen fertilization. *Agron. J.,* **107**: 2107-2021.

Sardana, V. and Zhang, G. P. (2005). Effect of time of nitrogen application on the growth and yield of two barley (*Hordeum vulgare* L.) cultivars. *Cereal Res. Commun.,* **33**: 255-257.

Shafi, M., Bakht, J., Jalal, F., Khan, M. A. and Khattak, S. G. (2011). Effect of nitrogen application on yield and yield components of barley (*Hordeum vulgare* L.). *Pak. J. Bot*., **43**: 1471-1475.

Sharma, R. K. and Verma, R. P. S. (2010). Effect of irrigation, nitrogen and varieties on the productivity and grain malting quality in barley. *Cereal Res. Commun.,* **38** : 419-428.

Sharma, S. K., Singh, J. and Midha, L. K. (2007). Response of barley (*Hordeum vulgare)* to fertility levels with and without green manuring under conserved soil moisture conditions. *Haryana J. Agron.,* **23** : 18-20.

Singh, B. (2005). *Effect of time of sowing and nitrogen application on grain yield and malt quality of barley varieties.* M.Sc. Thesis, Punjab Agricultural University, Ludhiana, India.

Singh, B. (2018). *Clipping and cutting management studies in barley (Hordeum vulgare L.).* Ph. D. Dissertation, Punjab Agricultural University, Ludhiana, India.

Singh, U., Singh, R. P., Panwar, K. S. and Singh, S. M. (1993). Effect of inoculation with *Azotobacters* on wheat (*Triticum aestivum* L.). *Indian J. Agron.,* **38**: 648-650.

Smith, E.G., O'Donovan, J.T., Henderson, W. J., Turkington, T. K. and McKenzie, R. H. (2012). Return and risk of malting barley production in western Canada. *Agron. J.,* **104**: 1374-1382.

Terefe, D., Desalegn, T. and Ashagre, H. (2018). Effect of nitrogen fertilizer levels on grain yield and quality of malt barley (*Hordeum vulgare* L.) varieties at Wolmera district, central highland of Ethiopia. *Int. J. Res. Studies in Agric. Sci.,* **4**: 29-43.

Therrein, M. C., Carmichael, C. A., Noll, J. S. and Grant, C. A. (1994). Effect of fertilizer management, genotype and environmental factors on some malting characteristics on barley. *Can. J. Plant Sci.,* **59**: 831- 837.

Vahamidis, P., Stefopoulou, A., Kotoulas, V., Lyra, D., Dercas, D. and Economou, G. (2017). Yield, grain size, protein content and water use efficiency of null-LOX malt barley in a semiarid Mediterranean agro ecosystem. *Field Crops Res.,* **206**: 115-127.

Verma, R. P. S., Kharub, A. S., Kumar, D., Sarkar, B., Selvakumar, R., Singh, R., Malik, R., Kumar, R. and Sharma, I. (2011). Fifty years of coordinated barley research in India. *Directorate of Wheat Research, Karnal-132001. Research Bulletin.,* **27**: 46.

Verma, R. P. S., Sarkar, B., Gupta, R. and Varma, A. (2008). Breeding barley for malting quality improvement in India. *Cereal Res. Commun.,* **36** : 135-145.

Verma, R. P. S., Sewa, R., Sarka,r B. and Shoran, J. (2004). *Malt barley Research in India.* Directorate at Wheat Research (ICAR) Post Box 158, Karnal 132001 (Haryana) India.

Weston, D. T., Horsley, R. D., Schwarz, P. B. and Goos, R. J. (1993). Nitrogen and planting date effects on low protein spring barley. *Agron. J.,* **85**: 1170-1174.

Yousif, A. M. and Evans D. E. (2018). The impact of barley nitrogen fertilization rate on barley brewing using a commercial enzyme (Ondea Pro). *J. Inst. Brew*., **124**: 132-142.

WEBLIOGRAPHY

Anonymous (2004). Progress report: *All India Co-ordinated Wheat and Barley Improvement Project: Directorate of Wheat Research*, **6** : 4.5-4.8.

Anonymous (2019a). Area, production and average yield of barley in World. *http://www.faostat.com.*

Anonymous (2019b). Area, production and average yield of barley in India. *http://www.indiastat.com.*