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**Dr. Amandeep Kaur**
Assistant Professor,
Department of Agronomy,
Lovely Professional University,
Phagwara, Punjab, India

**Ramandeep Kaur**
Ph.D. Scholar, Department of Agronomy, University of Nebraska, Lincoln, USA

**Corresponding Author:**
**Dr. Amandeep Kaur**
Assistant Professor,
Department of Agronomy,
Lovely Professional University,
Phagwara, Punjab, India

# Effect of different nitrogen levels on growth, yield, quality and nutrient uptake in malt barley (*Hordeum vulgare* L.): A review

**Dr. Amandeep Kaur and Ramandeep Kaur**

**Abstract**
Nitrogen plays a key role in cereal production because its requirement is highest among all the essential plant nutrients, therefore, care must be taken when the crop is taken for malt production. Grain yield and protein content are the characteristics strongly related to available nitrogen. It has been observed that higher nitrogen rates can result in translocation of excessive amount of nitrogen from vegetative organs to grains, thereby resulting in higher protein content and poor malt quality. Similarly lower rates of nitrogen application may result in reduced grain yield and quality below the acceptable levels. A proper supply of nitrogen to plants helps them to accumulate protein in their seeds and to increase their weight. Several researchers and eminent investigators observed that nitrogen dose varies with variety, soil type and location of the experiment. The review indicated that increasing levels of nitrogen application affected nearly all aspects of malt processing and malt quality. Grain protein levels increased with increasing nitrogen rates but malt extract levels decreased with increasing nitrogen levels. Therefore, appropriate nitrogen fertilization rates need to be applied for malt barley to achieve a balance between optimum grain yield and protein concentration.

**Keywords:** Barley, growth, malt quality, nitrogen levels, yield

## Introduction
Barley (*Hordeum vulgare* L.) is an important cereal crop in India. Rajasthan, Uttar Pradesh, Haryana, Punjab and Madhya Pradesh are the major barley growing states. The crop is considered 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. The barley varieties generally differ in their yield potential and malt quality parameters. Some varieties responded to higher nitrogen levels but other varieties responded to lower nitrogen levels. Therefore various research workers tried to evaluate the varieties with matching nitrogen levels that give good yield as well as malting characteristics.

Nitrogen is the most important element for realizing potential yield of any crop as its requirement is highest among all the essential plant nutrients. It is the most important input that affects both yield and quality of crops. The most important role of nitrogen in the plant is its presence in the structure of protein and nucleic acids, which are the most important building substances from which the living material or protoplasm of every cell is made. In addition, nitrogen is also found in chlorophyll, the green colouring matter of plants. It increases cell division and cell size elongation that influence growth and development parameters. Nitrogen is a main constituent of amino acids which are precursor to proteins. Grain protein and kernel plumpness are two most important quality parameters of malt barley which are strongly related to nitrogen application.

Barley crop has also been found to respond significantly to varying levels to nitrogen fertilization. Insufficient nitrogen can reduce grain yield and quality below acceptable levels, while excess nitrogen usually enhances undesirable high protein levels. This element influences the vegetative & reproductive growth and impacts on yield and yield attributing parameters (Nahvi *et al.*, 2012) [32]. A linear increase in grain yield and protein content with increasing nitrogen levels was observed by Dubey *et al.* (2018) [32]. Kouzegaran *et al.* (2015) [25] reported that increase in nitrogen dose from 0 to 150 kg $ha^{-1}$ resulted in significant increase in plant height, spike length and grain yield of barley, while Alghabari and Al-Solaimani (2015) [6] observed positive effect of nitrogen up to 200 kg $ha^{-1}$. Reddy and Singh (2018) [12, 43] recorded significant increase in number of effective tillers $m^{-2}$, number of grains $spike^{-1}$ and grain yield up to 75 kg N $ha^{-1}$. Terefe *et al.* (2018) [59] observed significant increase in number of tillers $m^{-2}$, number of grains $spike^{-1}$ and straw yield of malt barley up to 54 kg N $ha^{-1}$ but the grain yield increased only up to 36 kg N $ha^{-1}$. Similarly, Kassie and Tesfaye (2019) [21] reported significant increase in grain yield of malt barley up to 92 kg N $ha^{-1}$ but the grain protein content at this level exceeds the highest acceptable limit (11.5%) for malting. They concluded 48 kg N $ha^{-1}$ as optimum dose for acceptable grain quality for malt barley that gave highest net returns. Zhao *et al.* (2006) [68] reported that nitrogen content in grain is a determining factor of malt quality, higher grain nitrogen content not only lowers the carbohydrate content and malt extract level but also makes the barley grains more difficult to modify, causing problems for the malt production. Excessively higher protein content is undesirable because of the strong inverse co-relation between protein and carbohydrate content, thus high protein content leads to a low malt extract level (Thompson *et al.*, 2004) [60]. Therefore, appropriate dose of nitrogen need to be applied for malt barley to achieve a balance between optimum grain yield and protein concentration.

## Results and Discussion

### Effect of different nitrogen levels on growth parameters

Paramjit *et al.* (2001) [37, 56] from Hisar reported that plant height; number of tillers and DMA were significantly increased with each increment of nitrogen dose up to 90 kg $ha^{-1}$. Similarly, Saini and Thakur (1999) [45] also reported higher plant height with each successive increment of nitrogen level up to 90 kg $ha^{-1}$. Mian *et al*. (2001) [29] reported that application of 40, 80 and 120 kg N $ha^{-1}$ recorded statistically similar plant height in barley and it was significantly lower under control treatment. Moreno *et al.* (2003) [31] observed that maximum plant height, dry matter accumulation and LAI of barley were achieved with 120 kg N $ha^{-1}$ in comparison to lower doses. They observed that nitrogen deficiency caused reduction in light interception and leaf area index that resulted in lower grain yield. Similarly, Alam *et al*. (2005) [3] also observed that total biomass production and straw yield were increased with increasing levels of nitrogen. Sandhu (2006) [48] carried out a field experiment at Ludhiana and reported that significantly higher plant height and DMA of barley was achieved with 78 kg N $ha^{-1}$ over its lower doses. Minale *et al*. (2011) [30] also reported that nitrogen application significantly enhanced the plant height and LAI in barley. Shafi *et al*. (2011) [50] carried out an experiment on barley and reported that maximum (107.3 cm) plant height was noticed with 100 kg N $ha^{-1}$ followed by plant height (103.8 cm) with 80 kg N $ha^{-1}$. Maximum number of tillers $m^{-2}$ was observed with the application of 60 kg N $ha^{-1}$ as compared to other treatments. However, Singh *et al.* (2012) [53] observed that plant height and DMA were significantly increased up to 125% of the recommended dose of nitrogen. Kumar (2013) [26] concluded that nitrogen application led to significant increase in plant height, productive tillers $m^{-2}$ and dry matter accumulation in barley. Singh *et al*. (2001) [37, 56] & Narolia and Yadav (2013) [33] also reported that the increasing levels of nitrogen significantly increased the plant height and other growth attributes of malt barley up to the highest level of nitrogen. Singh *et al.* (2013) [54] reported that application of nitrogen at 93.75 kg $ha^{-1}$ produced significantly higher plant height and dry matter accumulation in barley as compared to 78.5 and 62.5 kg $ha^{-1}$. Similarly, Meena *et al*. (2012) [28] also observed that plant height and dry matter increased significantly with each successive dose of nitrogen up to 90 kg $ha^{-1}$.

Tigre *et al.* (2014) [61] carried out a field experiment at Ethiopia to find out the effects of various nitrogen doses on growth and yield components of barley. They observed that nitrogen application significantly prolonged the number of days to taken to heading, maturity and grain filling period. Number of fertile tillers, total biomass and straw yield were significantly increased by application of nitrogen. However, the effect of nitrogen on plant height and number of total tillers was not significant. Javaheri *et al*. (2014) [19] recorded the positive effect of nitrogen on stem growth and leaf area that resulted into taller plants with higher green area for more light interception and photosynthesis that leads to higher photo assimilates accumulation and translocation resulting in higher grain yield. Ejigu *et al.* (2015) [14] reported that the plant height of malt barley linearly increased with increasing levels of nitrogen. The lowest plant height of 93.3 cm was recorded in control as against 102.3 cm at 50 kg N $ha^{-1}$. They observed non-significant differences among different levels of nitrogen on spike length but it was increased from 18.7 to 19.3 cm as nitrogen rate increased from 0 to 50 kg N $ha^{-1}$. Kouzegaran *et al.* (2015) [25] reported that increase in nitrogen dose from 0 to 150 kg $ha^{-1}$ resulted in significant increase in plant height and spike length by 20.2 and 22.2%, respectively. Similarly, Alghabari and Al-Solaimani (2015) [6] observed that nitrogen application at 200 kg $ha^{-1}$ recorded maximum plant height and dry matter production in barley. While Alazmani (2015) [5] reported that 225 kg N $ha^{-1}$ significantly increased the plant height, leaf area, tiller count, LAI & LAD and this increase led to much greater production of dry matter in barley.

Reddy and Singh (2018) [12, 43] conducted a field experiment at Naini (UP) to find out the influence of four nitrogen doses (45, 60, 75 & 90 kg $ha^{-1}$) on growth parameters in barley. They observed that nitrogen application at 75 kg $ha^{-1}$ significantly enhanced the plant height, number of effective tillers, crop growth rate, relative growth rate and plant dry matter than 45 and 60 kg $ha^{-1}$ and statistically similar with 90 kg $ha^{-1}$. Terefe *et al.* (2018) [59] from Ethiopia reported that the crop took more days to heading (91.3) and physiological maturity (143) with 54 kg N $ha^{-1}$, while lesser number of days to heading (73.5) and physiological maturity (125) were taken under control treatment. They reported that this might be attributed to the behaviour of increased nitrogen that increased vegetative growth of the crop, thereby delayed heading time and physiological maturity. Similarly, application of 54 kg N $ha^{-1}$ produced the taller plants (93.4 cm), while the shorter plants (79 cm) were recorded in the control (0 kg N $ha^{-1}$). Such increment of plant height with increase in nitrogen dose might be related to the effect of nitrogen that promoted the vegetative growth as other growth factors are in conjunction with it.

### Effect of different nitrogen levels on yield and yield attributes

Mian *et al*. (2001) [29] reported that higher levels of nitrogen (80 and 120 kg N $ha^{-1}$) resulted in maximum number of effective tillers ad number of ears $m^{-2}$ in barley. Nitrogen application at 80 kg $ha^{-1}$ recorded significantly more number of grains ear$^{-1}$ and 1000-grain weight as compared to 120 kg N ha$^{-1}$ and control. The highest dose of nitrogen (120 kg ha$^{-1}$) reduced the grains number ear$^{-1}$ and test weight. The maximum grain yield (2522 kg ha$^{-1}$) was obtained with 80 kg N ha$^{-1}$ which was 73% higher than control treatment. Paramjit *et al.* (2001) [37, 56] reported that application of 90 kg N ha$^{-1}$ significantly increased the grain yield of malt barley at Hisar. The increase in grain yield with the application of higher dose of nitrogen was attributed to better growth and improvement in the yield attributing characters which finally improved the grain as well as straw yield of barley. Pertrie *et al.* (2002) [40] recorded significant increase in grain yield from 46.6 to 58.9 q ha$^{-1}$ with application of 55.5 kg N ha$^{-1}$ as compared to control. Cantero-Martinez *et al.* (2003) [9] also reported that N fertilization significantly enhanced the number of grains ear$^{-1}$ and grain yield of barley as compared to control. Patel *et al* (2004) [39] carried out an experiment at Vijapur and observed that significant increase in grain yield from 38.4 q ha$^{-1}$ to 42.2 q ha$^{-1}$ was recorded with increase in nitrogen dose from 60 to 100 kg ha$^{-1}$. The increased yield was attributed to improvement in growth and yield attributes. However, grain yield recorded at 80 and 100 kg N ha$^{-1}$ was statistically similar.

Singh and Singh (2005) [55] carried out a field experiment at Varanasi and observed that number of ears m$^{-2}$, grains ear$^{-1}$, test weight, grain yield and straw yield were significantly increased with increased doses of nitrogen from 20 to 80 kg ha$^{-1}$. The highest grain yield (31.5 q ha$^{-1}$) and straw yield (48.2 q ha$^{-1}$) were recorded with 80 kg N ha$^{-1}$. Physiological role of nitrogen in enhancing dry-matter accumulation might have led to increased yield attributes and thereby grain yield at higher rates of nitrogen. They further observed that the highest benefit: cost was recorded at 80 kg N ha$^{-1}$. Similarly Alam *et al*. (2005) [3] reported that increased nitrogen levels increased the grain yield in barley. Chakrawarti and Kushwaha (2006) [11] found that 90 kg N ha$^{-1}$ resulted in significantly more number of tillers m$^{-2}$, number of grains spike$^{-1}$, grain yield and straw yield of barley as compared to 0, 30 and 60 kg N ha$^{-1}$. Sandhu (2006) [48] from Ludhiana concluded that nitrogen application at 78 kg ha$^{-1}$ significantly improved the effective tillers, spike length, number of grains ear$^{-1}$, 1000-grain weight and grain yield of barley as compared to lower doses. Alam *et al.* (2007) [4] studied the effect of nitrogen fertilizer on yield and yield components of different varieties of barley. They reported that yield and yield components were significantly higher with 120 kg N ha$^{-1}$ as compared to other nitrogen levels. However, Rashid and Khan (2010) [42] recorded maximum grain yield of barley at 90 kg N ha$^{-1}$.

Safina (2010) [44] carried out two field experiments at Cairo to see the response of 3 nitrogen doses (50, 75 and 100 kg N fed$^{-1}$) with different genotypes of barley under saline irrigation water of 2496-2650 ppm in sandy soil. He reported that nitrogen levels significantly influence the spike length, number of grains spike$^{-1}$, grain yield, harvest index and straw yield except weight of grains per spike and seed index. Spike length, grains spike$^{-1}$ and straw yield fed$^{-1}$ were linearly increased with increasing N level. Application of 100 kg N fed$^{-1}$ was recommended for spike length, grains spike$^{-1}$ and straw yield fed$^{-1}$. The interaction effects indicated that combination of genotype Giza 123 and 75 kg N fed$^{-1}$ had the superiority in all studied characters except spike length, grains spike$^{-1}$ and HI, while genotype No.3 recorded the highest spike length with addition of 100 kg N fed$^{-1}$. He observed that 75 kg N fed$^{-1}$ in Giza 123 & Giza 127 genotypes and 50 kg N fed$^{-1}$ in exotic genotype No.3 gave highest productivity under saline sandy soil conditions. Sharma and Verma (2010) [51] reported that with increase in nitrogen dose from 30 to 90 kg ha$^{-1}$, there was significant increase in grain yield from 41.9 to 45.8 q ha$^{-1}$. They also observed that test weight improved up to 60 kg N ha$^{-1}$ and further increase in nitrogen application reduced the 1000-grain weight. The effect of nitrogen on the number of grains spike$^{-1}$ was not significant, however, an increase in number of grains spike$^{-1}$ was observed with each increase in nitrogen level. Malecka and Blecharczyk (2008) [27] also observed that application of higher dose of nitrogen (100 kg N ha$^{-1}$) showed an adverse effect on grain weight in barley. O'Donovan *et al.* (2011) [35] reported that number of tillers plant$^{-1}$ and grain yield of malt barley significantly increased with increasing rate of nitrogen up to 120 kg ha$^{-1}$.

Shafi *et al.* (2011) [50] carried out a field experiment at Peshawar to see the performance of different nitrogen doses on yield and yield components of barley. They observed that nitrogen application at 60 kg ha$^{-1}$ produced maximum number of productive tillers m$^{-2}$ (305.2), grains spike$^{-1}$ (27.1), 1000-grain weight (36.9 g), grain yield (2187 kg ha$^{-1}$) and biological yield (7481 kg ha$^{-1}$). Jankovic *et al.* (2011) [18] observed that application of nitrogen caused a significant improvement in the test weight and hectolitre weight. Different nitrogen rates (50, 70, 90 and 110 kg ha$^{-1}$) significantly enhanced the grain yield (2219 to 2987 kg ha$^{-1}$). Singh *et al.* (2012) [53] carried out a field experiment at Ludhiana to find out the influence of various nitrogen doses on yield and yield attributes of malt barley. They reported that different nitrogen levels in barley manifested significant impact on effective tillers, grains ear$^{-1}$ and test weight. Maximum number of ear bearing tillers and number of grains ear$^{-1}$ were obtained with application of 125% of recommended N, which were significantly higher than 100 and 75% of recommended N. Highest 1000-grain weight and grain yield was obtained with 125% of recommended N that was statistically similar with 100% of recommended N (62.5 kg ha$^{-1}$) but was significantly more than 75% of recommended N. Increased yield with increased nitrogen doses was due to increase in plant height, dry matter accumulation, effectives tillers, grains ear$^{-1}$ and 1000-grain weight. Straw yield was increased significantly with an increase in nitrogen level from 75 to 125% of recommended dose of nitrogen.

Narolia and Yadav (2013) [33] conducted an experiment at Rajasthan to study the performance of nitrogen levels on growth, yield and quality of malt barley under normal and late sown conditions. They reported that increasing nitrogen dose from 60 to 90 kg ha$^{-1}$ significantly enhanced the yield attributes, grain & straw yield, HI, protein concentration in grain and net returns in malt barley. Kumar (2013) [26] also observed that nitrogen application brought about improvement in yield attributes *viz.* productive tillers m$^{-2}$, ear length, number of grains ear head$^{-1}$ and 1000-grain weight and consequently resulted in significant improvement in grain and straw yield. Singh *et al.* (2013) [54] observed that different nitrogen levels showed significant effect on yield and yield attributing characters of barley. Nitrogen application at 93.75 kg ha$^{-1}$ produced more effective tillers, ear head length, grains ear$^{-1}$ and straw yield which were significantly higher than that obtained with 78.5 and 62.5 kg N ha$^{-1}$. The 1000-grain weight increased with each increment of nitrogen but it was statistically similar at 78.5 and 93.75 kg N ha$^{-1}$. Maximum grain yield was obtained with 93.75 kg N ha$^{-1}$ that was statistically similar with 78.5 kg N ha$^{-1}$ but significantly more than 62.5 kg N ha$^{-1}$. The highest harvest index was observed with 62.5 kg N ha$^{-1}$ in comparison to both higher levels of nitrogen. Contrary to the above findings, Castro *et al.* (2008) [10] and Sainju *et al.* (2013) [46] found that 1000-grain weight decreased with increase in nitrogen levels in malt barley.

Aghdam and Samadiyan (2014) [2] observed significant effect of nitrogen on number of tillers, number of fertile tillers and peduncle length of barley. Application of 150 kg N ha$^{-1}$ produced more number of total tillers, number of fertile tillers and peduncle length. Yesmin *et al.* (2014) [66] reported that yield and yield attributes of barley were significantly influenced by different nitrogen levels. They recorded highest grain yield (5.14 t ha$^{-1}$) with 100 kg N ha$^{-1}$ and lowest (3.14 t ha$^{-1}$) under control treatment. Khaled *et al.* (2014) [24] observed that nitrogen application under saline water irrigation showed positive effect on spikes m$^{-2}$, grains m$^{-2}$ and grain yield m$^{-2}$. O'Donovan *et al.* (2015) [36] and Sainju *et al.* (2015) [46] observed higher grain yield with increased nitrogen fertilization rates in malt barley. Ejigu *et al.* (2015) [14] conducted an experiment at Central Ethiopia to evaluate the effect of different nitrogen levels (0, 20, 30, 40 and 50 kg N ha$^{-1}$) on yield components and grain yield of malt barley varieties. They reported that number of days taken to 90% maturity and number of effective tillers plant$^{-1}$ increased significantly with increased levels of nitrogen fertilizer. The highest number of kernels spike$^{-1}$ (25.7) was obtained with application of 50 kg N ha$^{-1}$. The interaction effect of varieties and nitrogen rates were highly significant on biological yield and grain yield. The highest biological yield (130.0 q ha$^{-1}$) and grain yield (36.9 q ha$^{-1}$) were obtained from variety Miscal 21 at application of 30 kg N ha$^{-1}$. Among the four varieties, higher grain yield of malt barley was recorded in variety Miscal 21 at 30 kg N ha$^{-1}$ followed by variety Beka at 50 kg N ha$^{-1}$. Non-significant difference was also observed on harvest index at different levels of nitrogen, however, the harvest index increased as nitrogen rate increased from control (25.5%) to 40 kg N ha$^{-1}$ (35.7%) but declined at 50 kg N ha$^{-1}$ (25.9%).

Nega *et al.* (2015) [34] reported that biological yield in barley generally increased with the increase in nitrogen dose. They obtained maximum biological yield with 80.5 kg N ha$^{-1}$ whereas, lowest biomass yield was recorded in the control treatment. They further observed that the malt barley grain yield was significantly increased up to 69 kg N ha$^{-1}$. Puniya *et al.* (2015) [41] found that 90 kg N ha$^{-1}$ significantly improved the yield and yield attributes of barley over the control & 30 kg N ha$^{-1}$ and remained statistically similar with 60 kg N ha$^{-1}$. Amare and Adane (2015) [7] observed that grain yield of malt barley was significantly increased with increasing levels of nitrogen. Jadon *et al.* (2015) [17] recorded significantly higher growth attributes, yield parameter (except test weight), grain & straw yield and nitrogen uptake in grain and straw of barley under 120 kg N ha$^{-1}$ over 60 kg N ha$^{-1}$. Similarly, Kouzegaran *et al.* (2015) [25] also observed that increase in N fertilization increased the plant height, spike length and grain yield of barley. They recorded highest grain yield with 150 kg N ha$^{-1}$. Alghabari and Al-Solaimani (2015) [6] observed maximum spike number, spike weight, spike length, 1000-grain weight and grain yield with 200 kg N ha$^{-1}$. However, Alazmani (2015) [5] reported that nitrogen application up to 225 kg ha$^{-1}$ significantly improved yield components and grain yield of barley.

Kefale (2016) [23] studied the effect of nitrogen levels on grain yield of malt barley varieties at Ethiopia. Among different nitrogen levels, almost all agronomic parameters except harvest index were increased in response to nitrogen level up to 98.5 kg ha$^{-1}$. The maximum grain yield (4918 kg ha$^{-1}$) was recorded from variety Bahat with 98.5 kg N ha$^{-1}$. But the grain from this combination was beyond the acceptable grain protein contents for malting purpose. They observed that 75.5 kg N ha$^{-1}$ for variety Bahat recorded optimum (4578 kg ha$^{-1}$) yield with acceptable grain protein content for malt barley production. Reddy and Singh (2018) [12, 43] conducted a field study at Naini to see the influence of four nitrogen doses (45, 60, 75 and 90 kg N ha$^{-1}$) on yield attributes and yield of barley. They reported that effective tillers m$^{-2}$, spike length, grains spike $^{-1}$, grain yield (5.23 t ha$^{-1}$) and straw yield (8.37 t ha$^{-1}$) were significantly higher with 75 kg N ha$^{-1}$, whereas test weight was significantly improved with 45 kg N ha$^{-1}$. Terefe *et al.* (2018) [59] carried out a field study at Ethiopia to determine the performance of four nitrogen doses (0, 18, 36, and 54 kg N ha$^{-1}$) on grain yield of malt barley. They reported that tillers m$^{-2}$, grains spike $^{-1}$ and straw yield were significantly increased with increasing level of nitrogen up to 54 kg N ha$^{-1}$. Grain yield of malt barley increased up to 36 kg N ha$^{-1}$ and decreased thereafter at 54 kg N ha$^{-1}$. They observed that variety Ibon174/03 with 36 kg N ha$^{-1}$ generated optimum grain yield and the higher net profit.

Pradhan *et al.* (2018) [38] conducted the field experiments at New Delhi and observed that 160 kg N ha$^{-1}$ recorded more grain (12-33%) and above ground biomass (22-25%) yields and registered 9-20% higher total intercepted photosynthetically active radiation and 5-13% higher radiation use efficiency as compared to that with 40 kg N ha$^{-1}$. Dubey *et al.* (2018) [32] carried out field experiments at Faizabad to evaluate the performance of four nitrogen doses (0, 20, 40 and 60 kg ha$^{-1}$) on yield and yield attributes of barley. They found that 60 kg N ha$^{-1}$ produced significantly more number of spikelets spike$^{-1}$, spike length, number of grains spike$^{-1}$, test weight, grain yield, straw yield, biological yield and harvest index in comparison to 0, 20 and 40 kg N ha$^{-1}$. Highest net returns of Rs. 23593 ha$^{-1}$ and B: C (Rs. 1.04) was also recorded with application of 60 kg N ha$^{-1}$. Kassie and Tesfaye (2019) [21] conducted field experiments at Ethiopia to study the effect of five N levels (0, 23, 46, 69, and 92 kg ha$^{-1}$) on grain yield and grain characteristics of malting barley as well as to optimize the grain yield. They reported that various nitrogen levels significantly increased the 1000-kernel weight but did not significantly influence hectolitre weight. Grain yield also increased significantly with increasing nitrogen levels. Although grain yield increased with increased dose up to 92 kg N ha$^{-1}$, but grain protein content at this level exceeds the acceptable limit (11.5%). They further suggested that growers should limit nitrogen application in barley for malting purpose.

**Effect of different nitrogen levels on grain and malt quality**

Nitrogen is an important essential nutrient for plant growth which is required in large amount than all other major nutrients. Due to intensive cropping, most of the soils have been exhausted of this element as most of the farmers do not replenish the amount of nitrogen which is taken by the crop. It becomes important that nitrogen fertilization to barley has to be done with utmost care in relation to its production for specific purpose. Insufficient supply of nitrogen can reduce grain yield and quality below acceptable levels, while excess of nitrogen usually produces undesirable high protein content that may deteriorate the malt quality in barley. Fox *et al*. (2003) [16] reported that excessively higher protein content is undesirable, because of the strong inverse co-relation between protein and carbohydrate content, thus high protein content leads to a low malt extract level. Verma *et al.* (2003) [64] reported that nitrogen is the most important element for realising potential yield of crops but it increases protein content in grain which is undesirable for brewing. The higher nitrogen levels produced higher protein content in grain which is undesirable for malt recovery as malt extract is inversely related to grain protein content. They also observed that increasing level of nitrogen increased the diastatic power and decreased the wort filtration rate but these parameters were within the permissible limits even at 90 kg N $ha^{-1}$.

Xu *et al.* (2004) [65] reported that increasing N rates from 0 to 225 kg $ha^{-1}$ enhanced grain protein content but starch content was declined. Thompson *et al.* (2004) [60] found that addition of nitrogen fertilizer increased grain protein content above desirable levels. They concluded that there is need to apply appropriate nitrogen fertilization rates to malt barley for achieving a balance between optimum grain yield and protein concentration in grains. Satyajeet *et al.* (2006) [49] observed that 40 kg N $ha^{-1}$ significantly improved protein content in grain over control and 20 kg N $ha^{-1}$, but every successive dose of nitrogen beyond 40 kg $ha^{-1}$ did not cause significant increase in protein content, however every alternate dose i.e. 40 and 60 kg N $ha^{-1}$ remained at par, whereas 80 kg N $ha^{-1}$ gained significant increase in protein content over 40 kg N $ha^{-1}$. Zhao *et al.* (2006) [68] observed that nitrogen content in grain is a determining factor of malt quality, high grain nitrogen content not only means lower the carbohydrate content and malt extract level but also makes the barley more difficult to modify, causing problems for the malt production. They reported that nitrogen level should not be greater than 1.6–1.8% in grains for malt barley.

Singh and Singh (2005) [55] carried out a field study at UP and found that maximum protein content (11.7%) was observed with 80 kg N $ha^{-1}$ in comparison to 20, 40, and 60 kg N $ha^{-1}$. Sharma and Verma (2010) [51] found increased proportion of bold grains with 60 kg N $ha^{-1}$ while proportion of thin grains decreased with increase in nitrogen dose from 30 to 60 kg N $ha^{-1}$. Further increasing the nitrogen dose beyond 60 kg N $ha^{-1}$ reduced the proportion of bold grains. They observed lowest husk content at 90 kg N $ha^{-1}$. Safina (2010) [44] evaluated response of nitrogen rates (50, 75 & 100 kg N $fed^{-1}$) on quality parameters of barley with saline irrigation water of 2496-2650 ppm under sandy soil. The results showed that addition of 100 kg N $fed^{-1}$ produced highest total ash (2.34%), total fat (2.52%), crude protein content (15.1%) and crude fibers (2.13%). Jankovic *et al.* (2011) [18] concluded that grain quality was reduced (1.24 to 2.13%) by increasing nitrogen rates from 50 to 110 kg $ha^{-1}$ but different nitrogen rates showed a significant effect on the absolute grain weight (3.00 to 5.76 g) and volume grain weight (2.22 to 5.28 kg $hL^{-1}$). Increased nitrogen rates significantly affected the total protein content in grains. The increase in the total nitrogen rate (50, 70, 90 and 110 kg $ha^{-1}$), the protein content was increased (12.57, 12.84, 12.88 and 13.46%). In the control variant, malting barley grain had a significantly lower total protein content (11.33%) compared to the variants with the nitrogen fertilizer. They observed that with increase in the nitrogen rate, the total protein content of grain also significantly increased. The highest total protein content of grains was found in the variant with 110 kg $ha^{-1}$ of nitrogen. Minale *et al*. (2011) [30] also observed that increasing nitrogen rates in barley, significantly increased protein content. O'Donovan *et al.* (2011) [35] carried out field experiments at eight rainfed locations in western Canada to see the effects of five N (0, 30, 60, 90, and 120 kg $ha^{-1}$) rates on two-row barley cultivars AC Metcalfe and CDC Copeland. They observed that barley yield, kernel weight and tillers $plant^{-1}$ were increased with increasing nitrogen rate. Similarly the number of days taken to seed maturity and protein concentration in grains also increased but kernel plumpness and seed uniformity decreased. The increase in protein was less pronounced with cultivar CDC Copeland suggesting that there may be less risk with this cultivar of unacceptable protein levels at relatively high nitrogen rates. Barley plant stand decreased while lodging increased with increasing nitrogen rates. They suggested for selecting varieties with low protein and limit the nitrogen application. Smith *et al.* (2012) [57] also concluded that protein content in grains is an important factor for judging the quality for malting and brewing.

Singh *et al.* (2012) [53] studied the effect of different nitrogen levels on quality of malt barley at Ludhiana. They reported that highest protein content and test weight was obtained with application of 125% of recommended dose of nitrogen and these were significantly higher than 100 and 75% of recommended N. Nitrogen levels did not show significant impact on kernel plumpness and starch content. Although highest kernel plumpness and starch was found with 75% of recommended N followed by 100 and 125% of recommended N. Nitrogen doses significantly influenced the test weight, husk content, α-amylase activity and diastatic power of barley malt. The highest α-amylase activity was obtained with 125% of recommended N and it was statistically similar with 100% of recommended N but significantly more than 75% of recommended N. Similarly, highest test weight, husk content and diastatic power were obtained with 125% of recommended N. The malt recovery decreased with each increment of nitrogen dose. The highest malt recovery was obtained with 75% of recommended N which was significantly higher than with 100 and 125% of recommended N. Contrary to these findings, Edney *et al.* (2012) [13] reported that malt yield was not significantly influenced by application of different nitrogen levels. Singh *et al*. (2013) [54] observed that grain hardness, husk content, protein content and starch content in barley varied with different nitrogen levels. Maximum grain hardness, husk content and protein content was recorded with 93.75 kg N $ha^{-1}$ and was statistically similar with 78.5 kg N $ha^{-1}$ and significantly higher in comparison to 62.5 kg N $ha^{-1}$. The starch content decreased with each increase in nitrogen level. The maximum starch content was observed with 62.5 kg N $ha^{-1}$. Highest malt recovery was obtained with 62.5 kg N $ha^{-1}$ that was statistically similar with 78.5 kg N $ha^{-1}$ and significantly higher in comparison to 93.75 kg N $ha^{-1}$. Nitrogen application showed negative relation with malt recovery.

Narolia and Yadav (2013) [33] reported that with increase in N dose from 60 to 90 kg $ha^{-1}$ significantly enhanced protein concentration, average grain weight and α-amylase activity of malt barley. However, starch concentration and husk content were significantly higher under 60 kg N $ha^{-1}$. Positive effect of N application was also recorded by Valkama *et al*. (2013) [63] on grain protein contents and on α-amylase activity and diastatic power by Sandhu (2006) [48]. Amare and Adane (2015) [7] reported that with low available nitrogen in the soil, malt barley responded well to applied fertilizer and showed positive effect on protein content with increasing rates of nitrogen. Similarly, Nega *et al*. (2015) [34] observed that thousand kernel weight, kernel plumpness, hectolitre weight and grain protein content showed positive response to nitrogen application and higher values of these parameters were obtained at 69 kg N $ha^{-1}$ while lower values were recorded in the control treatment.

Alghabari and Al-Solaimani (2015) [6] observed that highest nitrogen and protein content in grains (2.64% and 16.52%) was found with 200 kg N $ha^{-1}$ and it was followed by 100 kg N $ha^{-1}$ (2.52%) while lower nitrogen and protein content in grains was observed under control treatment. Nitrogen fertilizer rate was a major factor affecting grain yield, quality and increased the test weight & protein content in barley (Sainju *et al.* 2015) [47]. O'Donovan *et al.* (2015) [36] reported that high grain protein content in grain barley caused reduction in extract yields for brewers. Kefale (2016) [23] observed that optimum dose of nitrogen for variety Bahat was 75.5 kg $ha^{-1}$ that produced optimum (4578 kg $ha^{-1}$) grain yield with acceptable grain protein content for malt barley production. However maximum grain yield was recorded with 98.5 kg N $ha^{-1}$. Vahamidis *et al.* (2017) [62] reported that grain protein content is one of the most important factors in marketing malting barley. They concluded that higher grain protein content due to more N rates is the reason for rejecting barley and marketed at cheaper rate.

Yousif and Evans (2018) [67] conducted a field experiment on two Australian (Buloke and Commander) and two Canadian (CDC Meredith and Bentley) barley varieties with various N doses (0, 20, 40 and 80 kg $ha^{-1}$). They observed that increased nitrogen fertilization resulted in increased barley kernel nitrogen content which significantly impacted a range of wort quality parameters including increased soluble nitrogen, free amino nitrogen and β-amylase level, but also reduced extract, colour and β-glucan level. Terefe *et al.* (2018) [59] conducted field experiments at Ethiopia to determine the influence of various nitrogen rates (0, 18, 36, and 54 kg N $ha^{-1}$) on quality characteristics in malt barley and reported significantly higher hectolitre weight and protein content with each increment in nitrogen rate. They observed that high nitrogen rates lead to high protein content in grains while low nitrogen rates recorded optimum grain yield with acceptable quality. They concluded that application of 36 kg N $ha^{-1}$ and variety Ibon174/03 generated acceptable quality for malt barley production. They also reported that increased protein content in grains increased the steep time, created undesirable qualities in the malt, excessive enzymatic activity and resulted in low extract yield. Kassie and Tesfaye (2019) [21] conducted field experiments at Ethiopia to evaluate the effects of nitrogen fertilization rates on quality characteristics of malting barley. The results showed that N rates significantly improved grain yield, protein content and kernel plumpness but had non-significant effect on hectolitre weight. On an average, the concentration of protein in grains increased by 0.84% for each rate of 23 kg N $ha^{-1}$. They concluded that although protein content in grains enhanced with increased nitrogen doses, but based on quadratic model, 48 kg N $ha^{-1}$ gave maximum net returns with acceptable protein content (11.5%).

## Effect of different nitrogen levels on nutrient content and uptake

Nitrogen concentration in both grain and straw and protein content in grain of barley was significantly improved with application of 90 kg N $ha^{-1}$ (Paramjit *et al*. 2001) [37, 56]. However, Campbell *et al*. (1993) [8] observed that grain N content of wheat increased in response to increasing rates of nitrogen application. Sinebo *et al.* (2004) also observed that N concentration in grain and straw was enhanced with increased nitrogen doses. Fageria and Baligar (2001) [15] reported that nitrogen uptake in grain showed positive significant relationship with grain yield. Singh and Singh (2005) [54] carried out field experiments at Varanasi and observed that N uptake in barley was significantly increased up to 80 kg N $ha^{-1}$, although both levels of 40 and 60 kg N $ha^{-1}$ were statistically similar. Sandhu (2006) [48] observed higher nitrogen uptake in barley with higher dose of nitrogen at 78 kg $ha^{-1}$ in comparison to lower doses. Kant *et al.* (2007) [20] from Israel reported that productivity of cereal crops is restricted in saline soils but may be improved by nitrogen nutrition. Under saline conditions, application of $NH_4^+$ and $NO_3^-$ led to a reduction of the detrimental effects of salt on growth. The $NH_4^+$ and $NO_3^-$ regime led to an increase in total N in control and saline treatments, but did not cause a large decrease in plant $Na^+$ content under salinity. Activities of GS, GOGAT, PEPC and AAT enzymes increased with salinity in roots, whereas there was decreased activity of the alternative ammonium assimilation enzyme GDH. The most striking effect of nitrogen regime was observed on GDH whose salinity-induced decrease in activity was reduced from 34% with $NO_3^-$ alone to only 14% with the mixed regime. The results suggested that the detrimental effects of salinity can be reduced by partial substitution of $NO_3^-$ with $NH_4^+$.

Shafi *et al.* (2011) [50] carried out field experiments on barley at Peshawar and concluded that maximum nitrogen content in grains and straw was observed with 60 kg N $ha^{-1}$. Similarly, Woldeyesus *et al.* (2004) and Muurinen (2007) also reported significant increase in straw nitrogen uptake with increased nitrogen doses. Singh *et al.* (2012) [53] observed that nitrogen, phosphorus and potassium uptake by grain and straw of malt barley were significantly increased with increase in nitrogen levels. Maximum NPK uptake by grain and straw of malt barley was recorded with 125% of recommended dose of nitrogen which was significantly higher as compared to that obtained with 100 and 75% of recommended dose of nitrogen. Taalab *et al.* (2015) [58] reported that increase in nitrogen level from 175 to 250 kg $ha^{-1}$ increased the nitrogen concentration in grains of barley. The maximum nitrogen concentration in grains was found with 250 kg N $ha^{-1}$ and the lowest under 175 kg N $ha^{-1}$. They also observed higher nitrogen uptake by grains and straw with 250 kg N $ha^{-1}$ as compared to 175 kg N $ha^{-1}$. Similarly, Agegnehu *et al.* (2016) [1] concluded that N concentration in grain and straw was improved with increased nitrogen doses.

Kassie and Tesfaye (2019) [21] conducted field experiments on malting barley at Ethiopia and reported that increase in nitrogen rates significantly increase the N concentration both in grains and straw. Kaur (2020) [22] reported that nitrogen levels showed significant variation with respect to grain yield of barley. Among different nitrogen levels, maximum grain yield was obtained with 90 kg N $ha^{-1}$ and it was statistically similar with 60 kg N $ha^{-1}$ but showed its significant superiority over 30 kg N $ha^{-1}$ and control. Application of 30, 60 and 90 kg N $ha^{-1}$ enhanced the grain yield by 25.3, 34.0 and 34.7%, respectively over control. Nitrogen application at 30, 60 and 90 kg $ha^{-1}$ increased the straw yield by 15.3, 25.4 and 28.4%, respectively over control. Significant and progressive increase in protein content in grains was observed with the increase in N level from 0 to 90 kg $ha^{-1}$.

**Table 1:** Effect of different nitrogen levels on grain yield, straw yield and protein content in malt barley under saline water irrigation (Pooled data of two years)

| Nitrogen levels (kg $ha^{-1}$) | Grain yield (q $ha^{-1}$) | Straw yield (q $ha^{-1}$) | Protein content (%) |
|---|---|---|---|
| 0 (Control) | 38.87 | 51.64 | 9.02 |
| 30 | 48.72 | 59.56 | 9.60 |
| 60 | 52.09 | 64.77 | 10.01 |
| 90 | 52.36 | 66.29 | 10.33 |
| S.Em ± | 0.24 | 0.39 | 0.05 |
| CD at 5% | 0.70 | 1.56 | 0.15 |

***Source***: Kaur (2020) [22].

So, it may be concluded that the response of various nitrogen levels differed with varieties, soil type and different agro climatic conditions.

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