Response of malt barley (Hordeum vulgare L.) varieties to different levels of nitrogen and sulphur application under agro-climatic zone IIIa (Semi-arid eastern plain zone) of Rajasthan

Abha Parashar, Sudesh Sharma, Prerna Dogra, Kamini Parashar and BS Tyagi

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Abstract
Field studies were carried out to investigate the effect of different nitrogen and sulphur applications on growth parameters, yield and quality parameters of two row malt barley varieties conducted at research farm, Rajasthan Agricultural Research Institute, Durgapura for two consecutive rabi seasons 2015-16 and 2016-17 on loamy sand soil. The twenty seven treatment combinations consisting of 3 varieties (RD 2849, DWRUB 52 and RD 2668), 3 nitrogen levels (60 kg, 90 kg and 120 kg) and 3 sulphur levels (0 kg, 10 kg and 20 kg) were tested in factorial randomized block design with three replications. The results indicated that variety RD 2849 proved significantly superior to DWRUB 52 and RD 2668 with respect to yield (grain and straw yield (q ha⁻¹)) and quality parameters (Starch content (%). In case of nitrogen and sulphur applications grain and straw yield (q ha⁻¹), Crude protein content (%) and Starch content (%) of barley were improved. The highest grain and straw yield (q ha⁻¹), Crude protein content (%) and Starch content (%) of barley obtained with 120 kg N ha⁻¹ and 20 kg S ha⁻¹ and it was found statically at par with 90 kg N ha⁻¹ and 10 kg S ha⁻¹ application.

Keywords: Hordeum vulgare L., nitrogen, sulphur, agro-climatic

Introduction
Barley (Hordeum vulgare L.) is an ancient cereal crop, which is used as food grain to a feed and malting grain (Baik and Ullrich 2008; Pourkheirandish and Komatsuda 2007) [4, 9]. It is considered fourth largest grown cereal crop in the world with a share of 7% of the global cereal production (Pal et al., 2012) [3]. Barley is also used as animal fodder, as a source of beverages and as a constituent of various health foods. The barley grains products such as “Sattu” (in summers because of its cooling effects on human body) and Missi Roti have been traditionally used in India (Verma et al. 2011) [12].

Barley ranks next to wheat both in area and production among rabi cereals in India. It is because of its less water requirement and fairly tolerance to salinity, alkalinity, frost and drought situations. Barley is generally grown on marginal and sub-marginal land farmers because of its low inputs. In Rajasthan, it is mostly grown on light texture soils that having low nitrogen and organic matter content with poor moisture retentive capacity.

Adequate mineral fertilization is considered to be one of the most important requirements for better yield. The major production constraints in barley growing areas are their low fertility status in general and deficiency of nitrogen in particular. Nitrogen is one of the essential nutrient that is universally deficient in most of the Indian soils particularly in the loamy sand soils of semi-arid regions of Rajasthan (Chhonkar and Rattan 2000) [3]. It is the most important growth limiting factor in non-legumes (Zebarth et al. 2009) [13]. Sulphur is also an essential nutrient for plants that helps in formation of important enzymes and assists in the formation of plant proteins. Enhanced removal of sulphur due to exploitation agriculture seems to be principal cause for occurrence of progressive incidence of sulphur deficiency. The interaction of nitrogen and sulphur is generally positive and occasionally additive. It has been established that for every 15 parts of nitrogen in proteins, there is one part of sulphur which implies that N-S ratio is fixed within narrow 15:1 range.

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Assistant Professor, Rajasthan Agricultural Research Institute, Durgapura for two consecutive rabi seasons 2015-16 and 2016-17 on loamy sand soil. The twenty seven treatment combinations consisting of 3 varieties (RD 2849, DWRUB 52 and RD 2668), 3 nitrogen levels (60 kg, 90 kg and 120 kg) and 3 sulphur levels (0 kg, 10 kg and 20 kg) were tested in factorial randomized block design with three replications. The results indicated that variety RD 2849 proved significantly superior to DWRUB 52 and RD 2668 with respect to yield (grain and straw yield (q ha⁻¹)) and quality parameters (Starch content (%). In case of nitrogen and sulphur applications grain and straw yield (q ha⁻¹), Crude protein content (%) and Starch content (%) of barley were improved. The highest grain and straw yield (q ha⁻¹), Crude protein content (%) and Starch content (%) of barley obtained with 120 kg N ha⁻¹ and 20 kg S ha⁻¹ and it was found statically at par with 90 kg N ha⁻¹ and 10 kg S ha⁻¹ application.

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Adequate mineral fertilization is considered to be one of the most important requirements for better yield. The major production constraints in barley growing areas are their low fertility status in general and deficiency of nitrogen in particular. Nitrogen is one of the essential nutrient that is universally deficient in most of the Indian soils particularly in the loamy sand soils of semi-arid regions of Rajasthan (Chhonkar and Rattan 2000) [3]. It is the most important growth limiting factor in non-legumes (Zebarth et al. 2009) [13]. Sulphur is also an essential nutrient for plants that helps in formation of important enzymes and assists in the formation of plant proteins. Enhanced removal of sulphur due to exploitation agriculture seems to be principal cause for occurrence of progressive incidence of sulphur deficiency. The interaction of nitrogen and sulphur is generally positive and occasionally additive. It has been established that for every 15 parts of nitrogen in proteins, there is one part of sulphur which implies that N-S ratio is fixed within narrow 15:1 range.

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Therefore, deficiency of sulphur will decrease the amount of protein synthesized even if there is plenty of N available to the plant. The aim of this study was to investigate the effect of different levels of sulphur and nitrogen amounts on yield and some quality components of barley grown on loamy sand soil.

Materials and Methods
The experiment was conducted at Rajasthan Agricultural Research Institute, Durgapura, Jaipur (Rajasthan) during Rabi seasons of 2015-16 and 2016-17, geographic location of the place is 75°47’ East longitude, 26°51’ North latitude and altitude of 390 m above mean sea level. The climate of this place is semi-arid characterized by extremity of temperature both in summer (45.5 °C) and winter (4 °C) and aridity of the atmosphere. The rainfall of the region is between 500-700 mm per annum which is mostly received during July to September. The experimental soil (0.0-0.15 m depth) analysed using the standard methods had shown pH 8.1 and 7.8, EC 0.17 dS m⁻¹ and 0.09 dS m⁻¹, organic carbon 0.19% and 0.24%, available N 134.2 and 139.2 kg ha⁻¹, available P₂O₅ 36.5 and 42.5 kg ha⁻¹, available K₂O 180.7 and 186.8 kg ha⁻¹, available Sulphur 7.10 and 8.75 ppm during the year 2015-16 and 2016-17, respectively. The treatments were consisted of three varieties RD 2552, K 560 and DL 88. Nitrogen application of 120 kg N ha⁻¹ also brought significantly higher grain yield compare to control and but was found at par with 90 kg N ha⁻¹(Table 1). Application of 120 kg and 90 kg N ha⁻¹ increased the grain yield of barley by 23.07 and 18.15% as compared to control, respectively, in pooled data. Similarly, application of 120 kg N ha⁻¹ recorded the highest straw yield and proved superior to control and was found at par with 90 kg N ha⁻¹ during both the years of experiment as well as in pooled analysis. Straw yield was recorded higher with increasing rates of N application might be due to improved biomass per plant at successive growth stages and increase in various morphological parameters like plant height, number of tillers etc. it has been also reported by Katiyar and Uttam (2007) [6] in barley and Jat et al. (2014) [9] in wheat. Sharma and Verma (2010) [10] also documented the significant positive influence of nitrogen on yield of barley. Sulphur significantly increased grain and straw yield during both the years of experiment as well as on pooled analysis. Among sulphur levels, application of 20 kg and 10 kg S ha⁻¹ increased the grain yield by 11.00 and 8.53% as compared to control, while the treatment 20 kg S ha⁻¹ was found at par with treatment 10 kg S ha⁻¹. As grain yield is primarily a function of cumulative effect of growth parameters and yield attributing characters, the higher values of these attributes because of sulphur and nitrogen application can be assigned as the most probable reason for significantly higher grain yield. Application of 20 kg S ha⁻¹ recorded the highest straw yield and proved superior to control and was found at par with 10 kg S ha⁻¹ during both the years of experiment as well as in pooled analysis. On the basis of pooled data, application of 20 kg and 10 kg S ha⁻¹ increased the straw yield by 8.82 and 6.64% as compare to control.

Quality parameters
Crude protein (%)
Varieties did not cause any significant variation in crude protein content during both the years of experimentation and in pooled analysis (Table 2). Nitrogen bought significant variation in crude protein during both the years of experimentation as well as in pooled analysis. Application of 120 kg N ha⁻¹ recorded the highest crude protein and proved significantly superior to control and was found at par with 90 kg N ha⁻¹ during both the years of experimentation as well as in pooled analysis. Application of 120 kg N ha⁻¹ increased the crude protein of barley by 12.80 and 11.08 per cent as compared to control, respectively, in pooled data. Similarly, application of 20 kg S ha⁻¹ recorded the highest crude protein and proved significantly superior to control and was found at par with 10 kg S ha⁻¹ during both the years of experimentation as well as in pooled analysis. Application of 20 kg and 10 kg S ha⁻¹ increased the crude protein of barley by 7.50 and 6.25 per cent as compared to control, respectively, in pooled analysis. Fathi et al. (1997) also reported an increase in the grain protein content up to highest rate of added N (0 to 105 kg N ha⁻¹).

Results and Discussion
Barley Yield
Barley varieties differ significantly in the grain and straw yield during both the year of experiment and on pooled data (Table 1). On the basis of pooled data, RD 2849 increased the grain yield by 9.21 and 12.91% as compared to varieties DWRUB 52 and RD 2668 respectively. Similarly, variety RD 2849 also recorded the highest straw yield (58.67 q ha⁻¹) and showed significant increase of 7.29 and 8.18%, respectively, over varieties DWRUB 52 and RD 2668 based on pooled analysis. Chakravarty and Kushwah (2007) [2] also reported the highest grain yield of variety RD 2552 among three varieties i.e. RD 2552, K 560 and DL 88. Nitrogen application of 120 kg N ha⁻¹ also brought significantly higher grain yield
Starch content (%)

Barley varieties responded significantly in the starch content during both the year of experimentation and on pooled basis. Variety RD 2849 proved significantly superior as compared to other varieties during both the years of experimentation. On the basis of pooled data, RD 2849 increased the starch content by 2.85 and 5.14 per cent, respectively as compared to variety DWRUB 52 and RD 2668. Nitrogen application significantly increased the starch content during both the years and in pooled analysis over control (Table 2). Among of nitrogen levels, application of 120 kg N ha⁻¹ recorded the highest starch content and proved significantly superior to control and was found at par with 90 kg N ha⁻¹ during both the years of experimentation as well as in pooled analysis. Application of 120 kg and 90 kg N ha⁻¹ increased the starch content of barley by 6.18 and 5.71 per cent as compared to control, respectively, in pooled data. Sulphur levels significantly increased starch content during both the years and in pooled analysis. Among of sulphur levels, application of 20 kg S ha⁻¹ recorded the highest starch content and proved significantly superior to control and was found at par with 10 kg S ha⁻¹ during both the years of experimentation as well as in pooled analysis. Application of 20 kg and 10 kg S ha⁻¹ increased the starch content of barley by 9.47 and 8.10 per cent as compared to control, respectively, in pooled data. Sulphur levels significantly and positively correlated with dry matter at physiological maturity, effective tillers, length of spike, number of grains per spike, test weight, malt yield, malt friability, malt homogeneity, hot water extract and hectoliter weight. The corresponding values for correlation coefficients were 0.98, 0.89, 0.93, 0.90, 0.98, 0.92, 0.96, 0.94, 0.85 & 0.97 during 2015-16 and 0.98, 0.85, 0.93, 0.92, 0.98, 0.90, 0.97, 0.94, 0.86 & 0.96 during 2015-16 and in pooled and 0.98, 0.87, 0.93, 0.91, 0.98, 0.91, 0.97, 0.94, 0.85 & 0.97 This indicates that yield attributes and malt quality parameters are directly correlated with the grain yield.

Correlation and regression

Simple correlation and regression were worked out between grain yield and dry matter at physiological maturity, effective tillers, length of spike, number of grains per spike, test weight, malt yield, malt friability, malt homogeneity, hot water extract and hectoliter weight. The corresponding values for correlation coefficients were 0.98, 0.89, 0.93, 0.90, 0.98, 0.92, 0.96, 0.94, 0.85 & 0.97 during 2015-16 and 0.98, 0.85, 0.93, 0.92, 0.98, 0.90, 0.97, 0.94, 0.86 & 0.96 during 2015-16 and in pooled and 0.98, 0.87, 0.93, 0.91, 0.98, 0.91, 0.97, 0.94, 0.85 & 0.97 This indicates that yield attributes and malt quality parameters are directly correlated with the grain yield.

The regression equations show that with the increase in one unit in dry matter at physiological maturity, effective tillers, length of spike, number of grains per spike, test weight, malt yield, malt friability, malt homogeneity, hot water extract and hectoliter weight, the corresponding grain yield increased by 0.192, 0.417, 3.57, 1.65, 1.47, 1.00,1.10, 1.15, 3.09 & 1.16 during 2015-16 and 0.173, 0.308, 3.60, 1.56, 1.25, 0.886, 1.05, 1.04, 2.82 & 1.04 during 2016-17 and in pooled 0.182, 0.359, 3.61, 1.60, 1.36, 0.94, 1.08, 1.10, 2.95 & 1.10 respectively.

Table 1: Response of malt barley varieties to nitrogen and sulphur on grain, straw yield and harvest index

| Treatments | Grain yield (q ha⁻¹) | Straw yield (q ha⁻¹) |
|------------|---------------------|---------------------|
|            | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled |
| Varieties  |         |         |        |         |         |        |
| RD 2668    | 39.48   | 40.73   | 40.11  | 53.61   | 54.85   | 54.23  |
| DWRUB 52   | 40.87   | 42.07   | 41.47  | 54.36   | 55.00   | 54.68  |
| RD 2849    | 44.80   | 45.77   | 45.29  | 57.66   | 59.68   | 58.67  |
| SEM⁺       | 0.90    | 0.96    | 0.66   | 1.01    | 1.09    | 0.74   |
| CD (P=0.05)| 2.56    | 2.73    | 1.85   | 2.87    | 3.10    | 2.09   |
| Nitrogen levels (kg/ha) |         |         |        |         |         |        |
| 60         | 36.43   | 37.92   | 37.18  | 50.03   | 50.53   | 50.28  |
| 90         | 43.40   | 44.45   | 43.93  | 56.76   | 58.48   | 57.62  |
| 120        | 45.32   | 46.20   | 45.76  | 58.84   | 60.52   | 59.68  |
| SEM⁺       | 0.90    | 0.96    | 0.66   | 1.01    | 1.09    | 0.74   |
| CD (P=0.05)| 2.56    | 2.73    | 1.85   | 2.87    | 3.10    | 2.09   |
| Sulphur levels (kg/ha) |         |         |        |         |         |        |
| 0          | 38.90   | 40.50   | 39.70  | 52.25   | 53.99   | 53.12  |
| 10         | 42.63   | 43.55   | 43.09  | 56.11   | 57.19   | 56.65  |
| 20         | 43.62   | 44.52   | 44.07  | 57.27   | 58.35   | 57.81  |
| SEM⁺       | 0.90    | 0.96    | 0.66   | 1.01    | 1.09    | 0.74   |
| CD (P=0.05)| 2.56    | 2.73    | 1.85   | 2.87    | 3.10    | 2.09   |
| NS = Non significant |

Table 2: Response of malt barley varieties to nitrogen and sulphur on crude protein, starch content and husk content

| Treatments | Crude protein content (%) | Starch content (%) | Husk (%) |
|------------|---------------------------|-------------------|---------|
|            | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled | 2015-16 | 2016-17 | Pooled |
| Varieties  |         |         |        |         |         |        |         |         |        |
| RD 2668    | 9.85    | 9.95    | 9.90   | 60.29   | 60.12   | 60.20  | 8.88    | 8.91    | 8.89   |
| DWRUB 52   | 9.98    | 10.15   | 10.07  | 64.43   | 61.66   | 61.54  | 8.95    | 8.98    | 8.97   |
| RD 2849    | 10.05   | 10.22   | 10.13  | 63.14   | 63.45   | 63.30  | 9.07    | 9.09    | 9.08   |
| SEM⁺       | 0.08    | 0.09    | 0.06   | 0.48    | 0.52    | 0.36   | 0.07    | 0.08    | 0.05   |
| CD (P=0.05)| NS      | NS      | NS     | 1.37    | 1.49    | 1.00   | NS      | NS      | NS     |
| Nitrogen levels (kg/ha) |         |         |        |         |         |        |         |         |        |
| 60         | 9.27    | 9.32    | 9.29   | 59.36   | 59.30   | 59.33  | 8.88    | 8.92    | 8.90   |
| 90         | 10.21   | 10.44   | 10.32  | 62.60   | 62.84   | 62.72  | 8.99    | 9.00    | 9.00   |
| 120        | 10.40   | 10.56   | 10.48  | 62.91   | 63.10   | 63.00  | 9.04    | 9.05    | 9.05   |
| S. No. | Treatments                                | Correlation coefficient (r) | Regression equation | Correlation coefficient (r) | Regression equation | Correlation coefficient (r) | Regression equation |
|-------|-------------------------------------------|----------------------------|---------------------|----------------------------|---------------------|----------------------------|---------------------|
| 1     | Dry matter at harvest                      | 0.981**                    | Y = -4.840+0.192 X | 0.983**                    | Y = 0.136 + 0.173 X | 0.982**                    | Y = -2.368 + 0.182 X |
| 2     | Effective tillers/plant                    | 0.890**                    | Y = -92.429 + 0.417 X | 0.852**                    | Y = -61.717 + 0.308 X | 0.872**                    | Y = -76.281 + 0.359 X |
| 3     | Number of grains/spike                     | 0.931**                    | Y = -49.981 + 3.575 X | 0.938**                    | Y = -56.314 + 3.605 X | 0.938**                    | Y = -53.825 + 3.616 X |
| 4     | Spike length (cm)                          | 0.909**                    | Y = 23.432 + 1.657 X | 0.921**                    | Y = 25.389 + 1.561 X | 0.915**                    | Y = 24.399 + 1.609 X |
| 5     | Test weight (g)                            | 0.982**                    | Y = -28.419 + 1.474 X | 0.985**                    | Y = -21.420 + 1.257 X | 0.986**                    | Y = -25.164 + 1.367 X |
| 6     | Malt yield                                | 0.925**                    | Y = -43.956 + 1.005 X | 0.903**                    | Y = -33.149 + 0.886 X | 0.915**                    | Y = -38.654 + 0.946 X |
| 7     | Malt friability                           | 0.965**                    | Y = -9.856 + 1.102 X | 0.975**                    | Y = -6.331 + 1.057 X | 0.971**                    | Y = -8.156 + 1.081 X |
| 8     | Malt homogeneity                          | 0.949**                    | Y = -46.900 + 1.159 X | 0.940**                    | Y = -37.404 + 1.046 X | 0.945**                    | Y = -42.168 + 1.103 X |
| 9     | Hot water extract                         | 0.853**                    | Y = -206.531 + 3.091 X | 0.860**                    | Y = -184.053 + 2.823 X | 0.857**                    | Y = -195.318 + 2.958 X |
| 10    | Hectoliter weight                         | 0.970**                    | Y = -27.813 + 1.162 X | 0.968**                    | Y = -20.809 + 1.046 X | 0.970**                    | Y = -24.415 + 1.105 X |

** Significant at 1 per cent level of significance

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