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Yield and malt quality of barley (*Hordeum vulgare*) impacted by nitrogen and sulphur application

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ABSTRACT

The study aimed to investigate the effect of different levels of nitrogen (N) and sulphur (S) doses on growth, yield and malt quality of different barley (*Hordeum vulgare* L.) varieties grown on loamy sand soil. A field experiment was conducted during *rabi* 2015–16 and 2016–17 with three barley varieties (RD-2668, DWRUB-52 and RD-2849), three levels of N (60, 90 and 120 kg/ha) and three levels of S (0, 10 and 20 kg/ha). The experiment was laid down in a factorial randomized block design with three replications. Result indicated that the barley variety RD-2849 recorded the highest growth, yield and malt quality compared to other varieties. Among the nutrients management practices, application of 120 kg N/ha and 20 kg S/ha documented the maximum growth and yield characters as well malt quality in barley, irrespective of varieties. Cultivation of barley variety RD-2849 with the application of 120 kg N/ha and 20 kg S/ha explore the maximum varietal potential under loamy sand soils of Rajasthan.

Keywords: Barley, Malt quality, Nitrogen, Sulphur, Yield

In Rajasthan, barley (*Hordeum vulgare* L.) is usually cultivated on light-textured soils that are low in nitrogen (N) and organic matter (OM) content with poor moisture retention capacity. Nitrogen is universally deficient in most of the Indian soils particularly in the loamy sand soils of semi-arid regions of Rajasthan. Among the nutrient N is the most commonly limiting in agricultural crop production. Consequently, almost all non-leguminous agricultural crops receive N inputs as mineral or organic fertilizers, or receive N inputs through biological N fixation by leguminous crops grown within the crop rotation. Proper management of these N inputs is critical to optimizing crop yield, and frequently also in optimizing crop quality attributes. Mineral fertilization is considered to be one of the most important inputs for better crop yield. It is the most important growth limiting factor for non-legumes (Zebarth *et al.* 2009).

Sulphur (S) is an essential nutrient for plants that helps in the formation of enzymes and proteins. Enhance removal of S due to exploitation agriculture seems to be the principal cause for the occurrence of progressive incidence of S deficiency. The interaction of N and S is generally synergistic and occasionally additive. It has been established that for every 15 parts of N in proteins, there is one part of S which implies that the N-S ratio is fixed within 15:1 range. Therefore, deficiency of S will decrease the amount of protein synthesized even if there is plenty of N available to the plant. Very limited information is available regarding N and S interaction on barley plant growth and yield attributes. Moreover, different varieties of the same plant (barley) differ in their ability to respond under different doses of nutrients, therefore, providing a unique opportunity to investigate their growth and yield attributes under various levels of nutrients application. Thus an effort has been made in the current investigation to examine the effect of different levels of N and S doses on yield and malt quality of different barley varieties grown on loamy sand soil of Rajasthan.

MATERIALS AND METHODS

The field experiment was conducted at Rajasthan Agricultural Research Institute, Durgapura, Jaipur, Rajasthan during *Rabi* 2015–16 and 2016–17. The treatments consisted of three barley varieties i.e. RD-2668 (V1), DWRUB-52 (V2), RD-2849 (V3), three levels of N i.e. 60 (N1), 90 (N2) and 120 kg/ha (N3) and three levels of S, i.e. 0 (S1), 10 (S2) and 20 kg/ha (S3). The experiment was laid down in a factorial randomized block design with three replications. Nitrogen and S was applied as per treatments through urea and gypsum, respectively. Recommended doses of

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phosphorus and potash were applied as basal dose through di ammonium phosphate and murate of potash. The barley varieties were sown on 15 and 19 November during 2015 and 2016, respectively. A seed rate of 100 kg/ha was used and 20 cm inter-row spacing was maintained. Sowing was done in the furrow, followed by irrigation up to field capacity.

Plant parameters: The crop growth rate (CGR) and relative growth rate (RGR) was recorded at 30-60 DAS, 60-90 DAS and 90 DAS-physiological maturity stage (PM). For calculating total tiller/m^2 and effective tillers/m^2, the total number of tillers and effective tillers, respectively were counted from selected plant in one meter square area from each plot. After harvesting, crop samples were air-dried for 2–3 days, followed by oven drying at 65˚C until the sample assumed constant weight. After threshing and winnowing grain and straw yields and harvest index was calculated.

The processed grain samples were subjected to micro malting on Joe white micro malting system by taking 100 g samples from each variety. Micro malting was done with 24 h steeping in three stages, 72 h germination in three stages and 24 h kilning in eight stages. To record friability in percentage, the friability meter is used to physically disintegrate the grain of malt and to separate its friable constituents from the hard constituents. Malt homogeneity is measured as per cent homogeneous malt using sample retained in malt friability meter mash during friability analysis and passing this fraction on sortimat for sieve analysis. The non-homogeneous fraction is that which is retained on the 2.2 mm sieve and rest is homogeneous (Verma *et al.* 2008).The data were statistically analyzed with a one-way analysis of variance (ANOVA) and significant difference level was set at $P<0.05$ for all statistical analysis.

RESULTS AND DISCUSSION

Growth parameters: Barley variety RD-2849 attained significantly higher CGR at 30-60 DAS, 60-90 DAS and 90 DAS-PM over DWRUB-52 and RD-2668, during both the years of study (Fig 1). In case of N, the application of 120 kg N/ha increased average CGR by 14.1, 22.4 and 34.2% at 30-60 DAS, 60-90 DAS and 90 DAS-PM, respectively over 60 kg N/ha (N1). Nitrogen accelerates carbohydrate conversion rate into protein as a main pathway in cell protoplasm structure, in turn enlarges cells such that its impacts are reflected morphologically on higher leaf area index (LAI) and crop growth rate (CGR) (Malmir *et al.* 2013). Similarly, application of 20 kg S/ha significantly increased the CGR at 30-60 DAS, 60-90 DAS and 90 DAS-PM over control during both the years of study.

The RGR of varieties did not differ significantly between 30 and 60 DAS, while, at 60-90 DAS and 90 DAS-PM, variety RD-2849 recorded the maximum RGR and proved significantly superior to RD-2668. Since, all the varieties were grown under identical agronomic practices and environmental conditions; the observed variation in CGR and RGR of varieties seems to be due to their genetic characteristics. These results confirm with the findings of Fisher *et al.* (2005) and Bakht *et al.* (2007). The application of 120 kg N/ha significantly increased the RGR between 60 and 90 DAS and 90 DAS-PM over 60 kg N/ha (N1) by 5.11% and 13.4%, respectively but it was found at par with 90 kg N/ha on these stages (Fig 2). Application S at 20 kg/ha significantly increased the RGR during 60-90 DAS and 90 DAS-PM over control, while, it was found at par with 10 kg S/ha during both the years of study and in average data. This might be due to the fact that application of S improves not only the availability of S but also other nutrients which are considered vitally important for the growth and development of plants (Gupta and Sehnug 2000).

Yield attributes and yield: On the basis of mean data of two years, the variety RD-2849 represented an increase

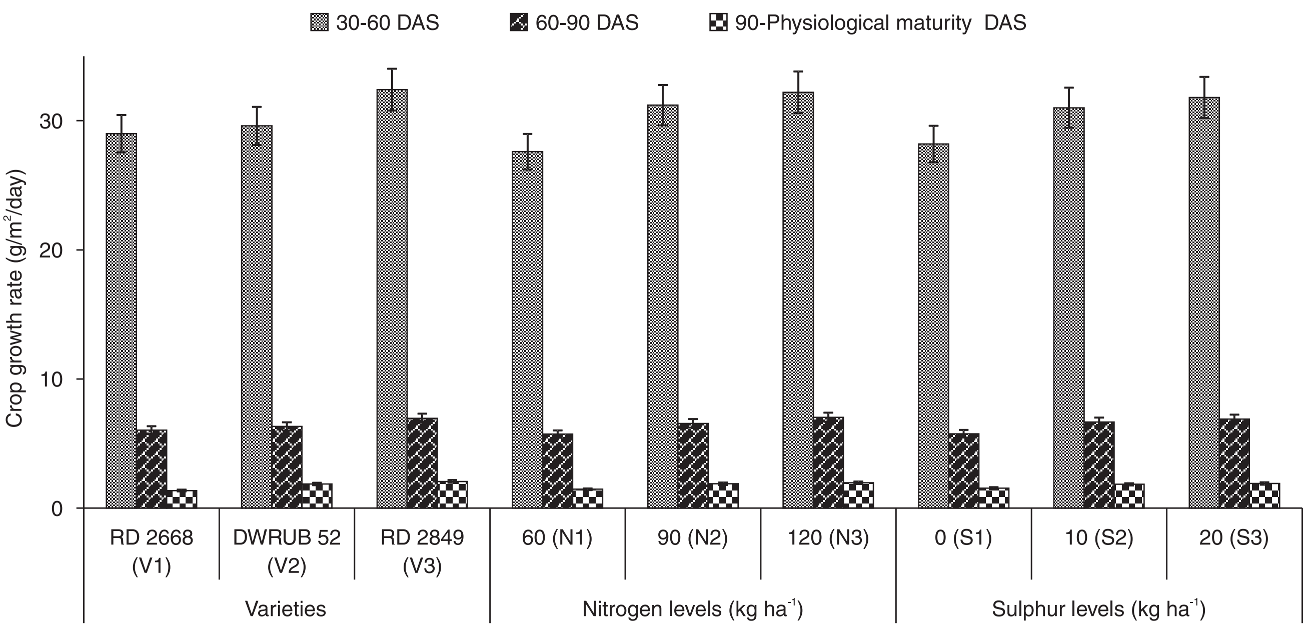

Fig 1 Effect of nitrogen and sulphur application on crop growth rate (g/m^2/day) at different growth stage of barley.

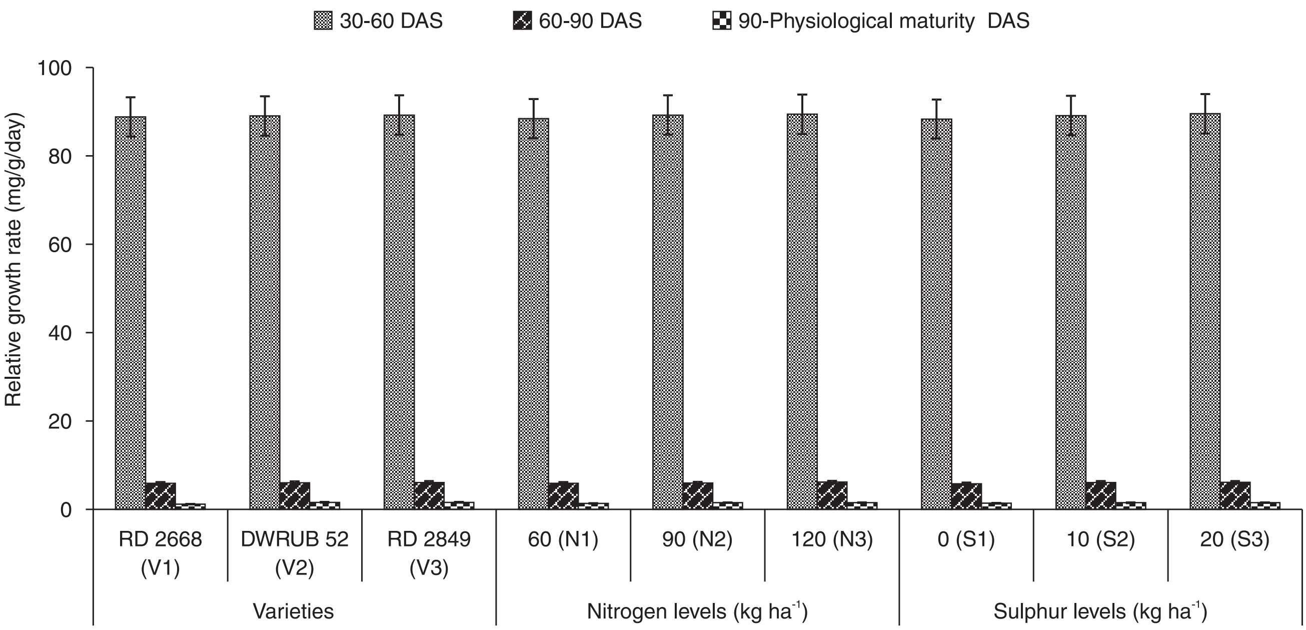

Fig 2 Effect of nitrogen and sulphur application on relative growth rate (mg/g/day) at different growth stage of barley.

of 1.73% and 6.51%, respectively over DWRUB-52 and RD-2668 varieties in total tillers/m^2 (Table 1). The N application of 120 kg/ha recorded highest number of total tillers/m^2 and proved significantly superior to 60 kg N/ha (N1) but it was found at par with 90 kg N/ha. Since, an adequate supply of N during initial stage of plant is considered important in promoting vegetative growth, ascending rates of N application increased the dry matter production through increasing the assimilating area and tillering, thereby increased the size of sink in terms of flowering and seed setting. Thus, N fertilization stimulated seed setting and enhanced the total tillers and effective tillers of plant. Similarly, application of 20 kg S/ha recorded the highest number of total tillers/m^2 compared to control, but

Table 1 Effect of nitrogen and sulphur application on yield and yield attributes of barley

Treatment	Total tiller per m^2		Effective tillers per m^2		Grain yield (q/ha)		Straw yield (q/ha)		Harvest index (%)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Varieties										
RD-2668 (V1)	10.1	10.2	25.4	27.3	39.5	40.7	53.6	54.9	42.4	42.6
DWRUB-52 (V2)	10.9	11.0	25.5	27.4	40.9	42.1	54.4	55.0	42.9	43.3
RD-2849 (V3)	12.2	12.4	26.0	27.8	44.8	45.8	57.7	59.7	43.7	43.4
SEm±	0.21	0.18	0.42	0.46	0.90	0.96	1.01	1.09	0.85	0.83
CD (P<0.05)	0.60	0.52	1.20	1.30	2.56	2.73	2.87	3.10	NS*	NS
Nitrogen levels (kg/ha)										
60 (N1)	8.90	8.94	24.4	26.3	36.4	37.9	50.0	50.5	42.1	42.9
90 (N2)	12.0	12.3	26.0	27.9	43.4	44.5	56.8	58.5	43.3	43.2
120 (N3)	12.2	12.4	26.6	28.4	45.3	46.2	58.8	60.5	43.5	43.3
SEm±	0.21	0.18	0.42	0.46	0.90	0.96	1.01	1.09	0.85	0.83
CD (P<0.05)	0.60	0.52	1.20	1.30	2.56	2.73	2.87	3.10	NS	NS
Sulphur levels (kg/ha)										
0 (S1)	9.24	9.55	24.5	26.5	38.9	40.5	52.3	54.0	42.6	42.8
10 (S2)	11.8	12.0	25.9	27.9	42.6	43.6	56.1	57.2	43.1	43.2
20 (S3)	12.0	12.1	26.6	28.1	43.6	44.5	57.3	58.4	43.2	43.3
SEm±	0.21	0.18	0.42	0.46	0.90	0.96	1.01	1.09	0.85	0.83
CD (P<0.05)	0.60	0.52	1.20	1.30	2.56	2.73	2.87	3.10	NS	NS

*NS–Non significant

Table 2 Effect of nitrogen and sulphur application on malt yield, malt friability and malt homogeneity of barley

Treatment	Malt yield (%)			Malt friability (%)			Malt homogeneity (%)		
	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean
Varieties									
RD-2668 (V1)	82.5	82.7	82.6	44.4	44.4	44.4	73.8	74.2	74.0
DWRUB-52 (V2)	84.3	85.4	84.9	45.7	45.4	45.6	75.8	75.9	75.9
RD-2849 (V3)	88.9	89.3	89.1	50.2	49.8	50.0	79.7	80.0	79.9
SEm±	0.54	0.75	0.46	0.36	0.41	0.27	0.40	0.54	0.34
CD (P<0.05)	1.52	2.13	1.30	1.03	1.17	0.77	1.12	1.53	0.94
Nitrogen levels (kg/ha)									
60 (N1)	82.1	82.7	82.4	43.1	42.7	42.9	73.3	73.5	73.4
90 (N2)	86.3	86.9	86.6	48.4	48.2	48.3	77.9	78.2	78.0
120 (N3)	87.3	87.8	87.6	48.9	48.8	48.8	78.3	78.5	78.4
SEm±	0.54	0.75	0.46	0.36	0.41	0.27	0.40	0.54	0.34
CD (P<0.05)	1.52	2.13	1.30	1.03	1.17	0.77	1.12	1.53	0.94
Sulphur levels (kg/ha)									
0 (S1)	81.3	81.6	81.5	43.6	43.7	43.6	73.4	73.5	73.4
10 (S2)	87.1	87.7	87.4	48.2	47.8	48.0	77.9	78.2	78.0
20 (S3)	87.4	88.1	87.7	48.7	48.2	48.4	78.2	78.4	78.3
SEm±	0.54	0.75	0.46	0.36	0.41	0.27	0.40	0.54	0.34
CD (P<0.05)	1.52	2.13	1.30	1.03	1.17	0.77	1.12	1.53	0.94

it was found at par with 10 kg S/ha during both the years of experiment as well based on average value.

In case of effective tillers/m^2, barley variety RD-2849 attained significantly higher number of effective tillers/m^2 over variety RD-2668 and it was found at par with the variety DWRUB-52 in pooled data of two years (Table 1). Application of 120 and 90 kg N/ha increased the effective tillers/m^2 by 4.53% and 3.05% as compared to 60 kg N/ha (N1), respectively. However, application of 20 and 10 kg S/ha increased the average effective tillers/m^2 by 3.60 and 2.95% as compared to control, respectively. This might be due to the fact that S addition improved the nutritional environment of rhizosphere as well as the plant system and ultimately the metabolic and photosynthetic activities resulting into better growth and development of plants. All that led to increased translocation of photosynthates towards sink and thus increased the number of grains/ear.

The barley varieties showed significant variation in the grain yield, variety RD-2849 increased the grain yield by 9.21 and 12.9% as compared to varieties DWRUB-52 and RD-2668, respectively. The higher yield of barley variety RD-2849 may be attributed to its higher biomass accumulation due to higher number of tillers and its proper partitioning as evident from equally higher yield attributes, i.e. effective tillers, length of spike (cm), number of grains per spike and 1000-grain weight. Chakravarty and Kushwah (2007) also reported the highest grain yield of variety RD-2552 among three varieties, i.e. RD-2552, K-560 and DL-88. Application of nitrogen @ 120 kg/ha also brought significantly higher grain yield compared to 60 kg N/ha (N1) and but it was found at par with 90 kg N/ha (Table 1). The results were in agreement with the observation of Sharma and Verma (2010), Yadeta and Patricia (2012), and Anbessa and Juskiw (2019). Among different S levels, application of 20 and 10 kg S/ha increased the grain yield by 11.0% and 8.53% over control, while applied 20 kg S/ha was found at par with treatment 10 kg S/ha. 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 S and N application can be assigned as the most probable reason for significantly higher grain yield.

Variety RD-2849 recorded the highest straw yield (58.67 q/ha) and showed significant increase of 7.29% and 8.18%, over varieties DWRUB-52 and RD-2668 respectively, based on two years pooled yield (Table 1). Capability of barley variety RD-2849 to produce higher straw yield seems to be primarily due to increase in morphological parameters (tillers/m row length) and stem thickness. Among of N levels, application of 120 kg N/ha recorded the highest straw yield and proved superior to 60 kg N/ha (N1) and it was found at par with 90 kg N/ha during both the years of experiment as well as two years pooled straw yield. 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. Similar findings were also reported by Katiyar and Uttam (2007) in barley and Jat *et al.* (2014) in wheat. On the basis of pooled data, application of 20 and 10 kg S/ha increased the straw yield by 8.82% and 6.64% as compared to control (S1).

Grain quality: Variety RD-2849 increased the malt yield by 4.98% and 7.84% as compared to varieties DWRUB-52 and RD-2668, respectively (Table 2). The improvement in varietal performance under this genotype (RD-2849) might be due to their genetic structure. Sardana and Zhang (2005) from China reported the superiority of variety 92-11 over Xiumei-3 for grain yield and malt quality parameters such as low β-glucan and high β-amylase activity, which they attributed to genetic constitutions of two varieties. The N levels significantly increased malt yield, application of 120 and 90 kg N/ha significantly increased the average malt yield by 6.24% and 5.09% over 60 kg N/ha (N1), respectively. The S application of 20 kg/ha recorded the highest malt yield and proved significantly superior to control, but it was found at par with 10 kg S/ha during both the years of experiment as well as in pooled data.

On the basis of mean data, RD-2849 increased the malt friability by 9.76% and 12.7% as compared to varieties DWRUB-52 and RD-2668, respectively (Table 2). Application of 120 and 90 kg N/ha increased the average malt friability by 13.8% and 12.6% over 60 kg N/ha (N1), respectively. The S levels, significantly increased the malt friability and application of 20 kg S/ha recorded the highest malt friability and proved significantly superior to control but it was found at par with 10 kg S/ha application. Barley variety RD-2849 increased the malt homogeneity by 5.27% and 7.94%, as compared to varieties DWRUB-52 and RD-2668, respectively (Table 2). Among of N levels, application of 120 kg N/ha recorded highest malt homogeneity but it was found at par with 90 kg N/ha. Among of S levels, application of 20 kg S/ha recorded significantly higher malt homogeneity over control and it was found at par with 10 kg S/ha. Sulphur application significantly increased malt diastatic power, alpha-amylase activity, friability and homogeneity, and decreased (1→3,1→4)-β-glucan concentration in the wort, indicating an improved endosperm modification during malting (Zhao *et al.* 2006).

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