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Effect of nitrogen and sulphur applications on growth, yield and quality parameters of malt barley (*Hordeum vulgare* L.) varieties under semi-arid eastern plain of Rajasthan

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Abstract
Field studies were carried out to investigate the effect of different nitrogen and sulphur applications on growth, yield and quality parameters of two row malt barley 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 RD2668), 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 growth parameters (Plant height, dry matter accumulation), Yield parameters (length of spike, 1000- grain weight) and quality parameters (malt homogeneity and hot water extract). In case of nitrogen and sulphur applications, plant height, dry matter accumulation, number of grains per spike, length of spike, 1000-grain weight, grain and straw yield, malt homogeneity and hot water extract (malt extract) of barley were improved. Significantly higher net returns were obtained with variety RD 2849, application of 120 kg N ha^{-1} and 20 kg S ha^{-1} independently while significantly higher B:C ratio were obtained with variety RD 2849 (1.83), application of 90 kg N ha^{-1} (1.83) and 10 kg S (1.75) independently.

Keywords: Barley, varieties, nitrogen, sulphur, yield, net return

Introduction
Barley (*Hordeum vulgare* L.) is an ancient cereal crop, which is used as food grain to feed and malting grain (Baik and Ullrich 2008; Pourkheirandish and Komatsuda 2007) [4, 20]. 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) [17]. 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) [29]. 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 nutrients that are universally deficient in most of the Indian soils particularly in the loamy sand soils of semi-arid regions of Rajasthan (Chhonkar and Rattan, 2000) [9]. It is the most important growth limiting factor in non-legumes (Zebarth *et al*., 2009) [31].

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. 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 varieties 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 $75^0 47'$ East longitude, $26^0 51'$ 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 (0-15 cm 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 P_2O_5 36.5 and 42.5 kg ha^{-1}, available K_2O 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-2668 (V1), DWRUB-52(V2), RD-2849(V3), three nitrogen levels 60(N1), 90(N2) and 120kg ha^{-1}(N3) and three sulphur levels Control (S1), 10 (S2) and 20 kg ha^{-1} (S3). The experiments were laid out in Factorial Randomized Block Design (RBD) with three replications. The treatments were randomly allotted to different plots using random number table of Fisher and Yates (1963). As per treatment, fertilizers were applied through urea, DAP and gypsum. Full dose of phosphorus and sulphur with half dose of nitrogen were applied as basal, while remaining nitrogen was top dressed according to treatments. The barley varieties *viz*. RD 2668, DWRUB-52 and RD 2849 were sown on 15th and 19th November during 2015 and 2016 as per treatments. A uniform seed rate of 100 kg ha^{-1} was used at inter row spacing of 20 cm. In order to obtain uniform plant stand, seeds were weighed for each plot separately in small packets before sowing. Sowing was done manually in furrows, followed by irrigation. Five plants were randomly selected from each plot and height of tagged plants was measured from ground level to the top of shoot at 30, 60, 90 DAS and at physiological maturity. The mean height was calculated and expressed in cm. The periodical change in dry matter accumulation at successive growth stages i.e., 30, 60, 90 DAS and at physiological maturity was recorded by collecting whole plant samples from the randomly selected area in second row of each plot by using 0.25 m row length. These samples were dried in sunlight for 2-3 days and finally dried in oven at 70˚C till constant weight was obtained. Thereafter, the samples were weighed for estimating total dry matter accumulation (g) at the above mentioned growth stages. To record the moisture percentage in grain, samples were taken replication wise and moisture content was predicted using FOSS NIR system and expressed in percentage. The hot water extract of wort, commonly called as malt extract was predicted using mash bath and expressed in percentage. The Kolbach index was calculated as the ratio of soluble nitrogen in the wort to the total nitrogen in the malt (Verma *et al.,* 2008) [30]. It represents the degree of modification of protein during malting and mashing. In order to evaluate the effectiveness of different treatments and ascertain the most remunerative treatment, total expenses incurred on cultural operations from preparatory tillage to harvesting including additional treatment cost for each treatment were computed and subtracted from the respective gross income to workout net monetary returns ₹ ha^{-1}. Gross income was computed taking prevailing market prices of the commodities. Thus, net return was computed as:

Net return (₹ ha^{-1}) = Gross return (₹ ha^{-1}) – cost of total inputs (₹ ha^{-1})

The B:C ratio was calculated for each treatment by dividing net return with cost of cultivation. To test the significance of variation in experimental data of various treatment effects, the data were statistically analyzed as described by Panse and Sukhatme (1985) [19]. The critical differences were calculated to assess the significance of treatment means, wherever the 'F' test was found significant at 5% level of probability.

Results and Discussion

Growth parameters

Barley varieties did not show significant variation in their plant height at 30 DAS, while, at 60 DAS, variety RD 2849 was found significantly taller to RD 2668 but was at par with DWRUB 52. At later stages (90 DAS and at physiological maturity) the variety RD 2849 was found significantly taller as compare to other two varieties (DWRUB-52 and RD 2668) (Table 1). On the basis of pooled data variety RD 2849 increases plant height at 60 DAS by 6.22%, at 90 DAS by 16.05% and at physiological maturity by 15.29%, respectively over variety RD 2668. It is an established fact that growth, development and yield potential of variety is an outcome of genomic, environmental and agronomic interactions. Since, all the varieties were grown under identical agronomic (management) practices and environmental conditions; the observed variation in overall growth of varieties seems to be due to their genetic milieu. Marked variations in various growth characters of varieties were also observed by several workers (Ali 2011, Singh *et al.*, 2013a, Alazmani 2015 and Pankaj *et al.*, 2015) [2, 27, 1, 18]. The difference in plant height, 60 DAS, 90 DAS to physiological maturity of different varieties is due to genetic characteristics of variety. Varietal differences for plants height were also reported by Sardana and Zhang (2005a) [23] and Pankaj *et al.,* (2015) [18]. Similarly, nitrogen application did not bring significant variation in plant height at 30 DAS. While, application of 120 kg and 90 kg N ha-1 increased the pooled plant height by 5.52 and 4.89% at 60 DAS and 20.14 and 16.11% at 90 DAS and 15.35 and 11.61% at physiological maturity as compared to control, respectively. In case of sulphur, application of 20 kg and 10 kg S ha-1 increased the pooled plant height by 6.24 and 5.87% at 60 DAS, 16.46 and 12.67% at 90 DAS and 13.19 and 9.39% at physiological maturity as compared to control, respectively. The difference in plant height of different varieties at 60, 90 DAS and physiological maturity may be due to genetic characteristics of variety. These results confirm the findings of Fishar *et al.,* (2005) and Bakht *et al.,* (2007) [5]. Varieties did not differ significantly in dry matter accumulation at 30 DAS, while, at 60, 90 DAS and at physiological maturity, variety RD 2849 accumulated more dry matter at 60 DAS by 11.34%, at 90 DAS by 11.99% and at physiological maturity by 13.37%, respectively over variety RD 2668. The improvement in these growth parameters might have led to higher interception and absorption of radiant energy, resulting into greater photosynthesis and finally dry matter accumulation (Sharma *et al*. 2000) [25]. Nitrogen did not bring any significant variation in dry matter accumulation at 30 DAS. While, significant increase in dry matter accumulation at 60, 90 DAS and at physiological maturity was observed due to application of 120 kg N ha^{-1}. Increase in dry matter production because of nitrogen application may be because nitrogen helped in rapid cell multiplication and enhanced chlorophyll synthesis, thereby increased the photosynthetic rate and ultimately increased supply of assimilates to the plant which in turn increased the growth in terms of dry matter production. The results of present investigation are in close agreement with findings of Singh *et al.*, (2003) [28], Kumawat and Jat (2005) [14] and Narolia (2009) [16] in barley and Jat *et al.*, (2014) [11] in wheat. Sulphur application of 20 kg and 10 kg S ha-1 increased the pooled dry matter accumulation by 12.26 and 9.55% at 60 DAS, 13.43 and 10.53% at 90 DAS and 13.87 and 10.91% at physiological maturity as compared to control, respectively. Sulphur application at 30 DAS did not showed significant variation in dry matter accumulation (Table 1). The Sulphur application will led to increase absorption of other nutrients which might increase the metabolic activities and photosynthetic rate resulting in improved plant height and the dry matter production. These reporting's are in close conformity with those of Kaushik and Sharma (1997) [13] and Kumawat *et al*., (1999) [15].

Yield attributes

It is evident from results that variety RD 2849 was superior over RD 2668 in terms of yield attributing characteristics *viz*. length of spike (cm), number of grains per spike and test weight as compared to other varieties (Table 2). Consequently, RD 2849 variety results in significantly higher grain yield and straw yield as compare to RD 2668 and DWRUB 52. The test weight of variety RD 2849 was highest which was significantly higher as compared to variety RD 2668 and DWRUB 52. This might be due to the fact that RD 2849 variety has bolder grains compared to other varieties. However, the suitable genetic behavior of RD 2849 variety with environmental factors which is may lead to an increase in photosynthesis process and accumulation of carbohydrates in grains to produce heavy grains and consequently increased test weight. Similar results were also reported by Zeidan (2007) [32], Rashid and Khan (2008) [22], Bagheri and Sadeghipour (2009) [3], Ali (2011) [2], Ram and Dhaliwal (2012). As yield attributes is primarily a function of cumulative effect of growth parameters, the higher values of these attributes because of sulphur and nitrogen application can be assigned as the most probable reason for significantly higher length of spike (cm), number of grains per spike and 1000- grain weight. Similarly, Maximum yield response was obtained with an application of between 10 and 20 kg S/ha by Zhao *et al*., (2006) [33] at UK.

Quality parameters

Different treatments failed to cause significant variation in moisture % of barley grain during both years of research and in pooled data (Table 3). However, on the basis of pooled data, RD 2849 increased the hot water extract by 3.56 and 7.23%, as compared to varieties DWRUB 52 and RD 2668, respectively. The improvement in varietal performance under this genotype (RD 2849) might be due to their genetic makeup. 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 nitrogen levels significantly increased hot water extract during both the years and in pooled analysis over control. Among of nitrogen levels, application of 120 kg N ha-1 recorded the highest hot water extract and proved significantly superior to control but was found at par with 90 kg N ha-1 during both the years of experiment as well as in pooled analysis. Application of 120 kg and 90 kg N ha-1 significantly increased the hot water extract by 4.05 and 3.74% over control, respectively, in pooled analysis. Sulphur levels significantly increase hot water extract during both the years and in pooled analysis over control. Among of sulphur levels, application of 20 kg S ha-1 recorded the highest hot water extract and proved significantly 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. Application of 20 kg and 10 kg S ha-1 increased the hot water extract by 4.89 and 3.44% over control, respectively, in pooled analysis. Data regarding kolbach index (%) revealed that barley varieties differ significantly in the kolbach index during both the year of experiment and on the pooled basis. Variety RD 2849 increased the kolbach index by 5.24 and 6.36% as compared to varieties DWRUB 52 and RD 2668, respectively, however, variety DWRUB 52 was found at par with the variety RD 2668. Nitrogen levels significantly bring variation in kolbach index during both the years and in pooled analysis. Among of nitrogen levels, application of 120 kg N ha-1 recorded the highest kolbach index and proved significantly 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. Among of sulphur levels, application of 20 kg S ha-1 recorded the highest kolbach index and proved significantly 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. Application of 20 kg and 10 kg S ha-1 significantly increased the kolbach index by 7.86 and 7.01% over control, respectively, in pooled analysis to control, respectively. As S-deficient sites, S applications significantly affected malting quality, resulting in increased activities of hydrolytic enzymes and improved endosperm modification during malting, as well as increased concentration of the DMS precursor in the kilned malt (Zhao *et al*., 2006) [33].

Economics

There was significantly higher net return was obtained with RD 2849 during both the years as well as in pooled data, variety RD 2849 were found higher by ₹ 6938 ha-1 and ₹ 9029 ha-1, over varieties DWRUB 52 and RD 2668, respectively in pooled analysis (Table 3). The nitrogen application of 120 kg and 90 kg N ha-1 recorded higher net returns by 36.89 and 29.51% over control, respectively in pooled analysis.

Sulphur application of 20 kg and 10 kg S ha-1 recorded significantly higher net return by 17.01 and 13.29% over control, respectively in pooled analysis.

There was significant difference among varieties for B:C ratio. The maximum B:C ratio were obtained with RD 2849 during both the years as well as in pooled data, which were higher by 10.90 and 15.82%, respectively over variety

DWRUB 52 and RD 2668 on pooled basis (Table 4). The nitrogen application of 90 kg N ha-1 significantly increased the B:C ratio as compared to control during both the years and in pooled data, but it was found at par with 120 kg N ha-1. Similarly, sulphur application of that 10 kg S ha-1 significantly increased B:C ratio as compared to control during both the years and in pooled data, but it was at par with 20 kg S ha-1. This trend in economic returns was basically owing to the treatment effect on the grain and straw yield, similar results were reported by Jat *et al*., (2014) [11] and Chauhan (2014) [8].

Table 1: Influence of malt barley varieties and application of nitrogen and sulphur on plant height (cm) and dry matter accumulation at different intervals (mean data of 2 years)

Treatments	Plant height (cm)				Dry matter accumulation (g /m row length)			
	30 DAS	60 DAS	90 DAS	At physiological maturity	30 DAS	60 DAS	90 DAS	At physiological maturity
Varieties								
RD 2668	20.69	81.32	83.45	87.60	13.02	187.21	223.42	231.60
DWRUB 52	21.29	85.79	87.99	90.12	13.23	191.09	229.06	240.28
RD 2849	21.53	86.38	96.83	100.99	14.33	208.45	250.21	262.58
S.Em+	0.29	1.16	1.31	1.28	0.39	2.59	3.15	3.37
CD (P=0.05)	NS	3.24	3.68	3.60	NS	7.26	8.83	9.44
Nitrogen levels (kg/ha)								
60	20.78	81.66	79.78	85.24	12.57	178.40	212.85	221.61
90	21.29	85.66	92.64	95.14	13.82	201.17	240.51	251.77
120	21.44	86.17	95.85	98.33	14.18	207.17	249.34	261.09
S.Em+	0.29	1.16	1.31	1.28	0.39	2.59	3.15	3.37
CD (P=0.05)	NS	3.24	3.68	3.60	NS	7.26	8.83	9.44
Sulphur levels (kg/ha)								
0	20.69	81.22	81.51	86.40	12.87	182.32	216.90	226.14
10	21.34	85.99	91.84	94.52	13.77	199.74	239.76	250.83
20	21.49	86.29	94.93	97.80	13.94	204.69	246.04	257.51
S.Em+	0.29	1.16	1.31	1.28	0.39	2.59	3.15	3.37
CD (P=0.05)	NS	3.24	3.68	3.60	NS	7.26	8.83	9.44

NS = Non significant

Table 2: Response of malt barley varieties to nitrogen and sulphur on yield attributes (spike length, number of grains per spike, test weight)

Treatments	Spike length (cm)		Number of grains per spike		Test weight (g)	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Varieties						
RD 2668	10.05	10.21	25.37	27.26	45.94	49.49
DWRUB 52	10.90	11.01	25.54	27.43	47.29	50.84
RD 2849	12.16	12.37	26.04	27.83	49.50	53.08
S.Em+	0.21	0.18	0.42	0.46	0.53	0.51
CD (P=0.05)	0.60	0.52	1.20	1.30	1.50	1.45
Nitrogen levels (kg/ha)						
60	8.90	8.94	24.43	26.26	43.77	47.13
90	12.02	12.25	25.97	27.87	49.41	53.02
120	12.19	12.39	26.55	28.40	49.55	53.26
S.Em+	0.21	0.18	0.42	0.46	0.53	0.51
CD (P=0.05)	0.60	0.52	1.20	1.30	1.50	1.45
Sulphur levels (kg/ha)						
0	9.24	9.55	24.51	26.53	46.07	49.05
10	11.84	11.96	25.86	27.89	48.11	52.00
20	12.03	12.07	26.58	28.10	48.55	52.36
S.Em+	0.21	0.18	0.42	0.46	0.53	0.51
CD (P=0.05)	0.60	0.52	1.20	1.30	1.50	1.45

NS = Non significant

Table 3: Response of malt barley varieties to nitrogen and sulphur on grain moisture, hot water extract (malt extract) and Kolbach index

Treatments	Moisture (%)			Hot water extract (%)			Kolbach index (%)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Varieties									
RD 2668	8.73	8.68	8.70	77.94	78.16	78.05	37.45	37.59	37.52
DWRUB 52	8.84	8.72	8.78	80.60	81.04	80.82	37.86	37.99	37.92
RD 2849	8.91	8.74	8.83	83.37	84.03	83.70	39.78	40.05	39.91
S.Em+	0.08	0.07	0.05	0.92	0.98	0.67	0.27	0.32	0.21
CD (P=0.05)	NS	NS	NS	2.60	2.77	1.87	0.78	0.92	0.60
Nitrogen levels (kg/ha)									
60	8.76	8.65	8.70	78.62	79.00	78.81	37.00	36.97	36.98

90	8.84	8.72	8.78	81.52	82.00	81.76	38.94	39.02	38.98
120	8.89	8.77	8.83	81.77	82.24	82.00	39.14	39.64	39.39
S.Em+	0.08	0.07	0.05	0.92	0.98	0.67	0.27	0.32	0.21
CD (P=0.05)	NS	NS	NS	2.60	2.77	1.87	0.78	0.92	0.60
Sulphur levels (kg/ha)									
0	8.73	8.65	8.69	79.01	79.10	79.06	36.61	36.66	36.64
10	8.82	8.73	8.78	81.65	81.91	81.78	39.12	39.29	39.21
20	8.93	8.76	8.85	81.25	82.22	81.74	39.35	39.68	39.52
S.Em+	0.08	0.07	0.05	0.92	0.98	0.67	0.27	0.32	0.21
CD (P=0.05)	NS	NS	NS	2.60	2.77	1.87	0.78	0.92	0.60

NS = Non significant

Table 4: Response of malt barley varieties to nitrogen and sulphur on net returns and B:C ratio

Treatments	Net returns (₹ ha^{-1})			B:C ratio		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Varieties						
RD 2668	44810	47056	45933	1.40	1.76	1.58
DWRUB 52	47056	48992	48024	1.47	1.82	1.65
RD 2849	53878	56046	54962	1.69	1.97	1.83
S.Em+	1351	1691	1082	0.03	0.04	0.03
CD (P=0.05)	3835	4800	3036	0.09	0.12	0.08
Nitrogen levels (kg/ha)						
60	39499	41786	40643	1.25	1.59	1.42
90	51558	53715	52637	1.68	1.98	1.83
120	54688	56592	55640	1.69	1.90	1.80
S.Em+	1351	1691	1082	0.03	0.04	0.03
CD (P=0.05)	3835	4800	3036	0.09	0.12	0.08
Sulphur levels (kg/ha)						
0	43617	46553	45085	1.37	1.77	1.57
10	50220	51940	51080	1.57	1.93	1.75
20	51908	53600	52754	1.62	1.85	1.74
S.Em+	1351	1691	1082	0.03	0.04	0.03
CD (P=0.05)	3835	4800	3036	0.09	0.12	0.08

NS = Non significant

Conclusion

On the basis of two-year experimentation, it may be concluded that, barley variety RD 2849 with application of 90 kg N ha-1 and 10 kg S ha-1 proved the most efficient and economically viable treatment combination which was found most effective for better malt quality.

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