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Response of barley (*Hordeum Vulgare* L.) varieties to different levels of Sulphur

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Abstract
An experiment on response of barley (*Hordeum vulgare* L.*)* varieties to different levels of sulphur was conducted ITM University, Gwalior during rabi season of 2015 -2016. The combination of three barley varieties (super luxmi, NDB-2, NDB-1173) and four levels of sulphur (0, 10, 20, and 30 kg ha^{-1}) were tested in split plot design with three replications. The variety super laxmi recoded higher number of tillers, dry matter production, effective tillers, spike length, grain number per spike and number of spikelet over other two varieties under test. The 1000 grain weight, grain yield, straw yield and biological yield were also higher with super laxmi variety over NDB-2 and NDB-1173. Application of sulphur at 30 kg ha^{-1} has increased the leaf number per culm, tiller number, effective tillers, spike length, grain number, grain and straw yield which was significantly higher lower levels of sulphur application.

Keywords: Barley, sulphur, Grain yield, Harvest index

Introduction
In India, barley is cultivated on about 6.95 lakhs ha area with production of 17.43 lakhs tons and productivity of 2508 kg/ha (Anonymous, 2013). The major barley growing states in India are Rajasthan, Uttar Pradesh, Haryana, Punjab, Madhya Pradesh, Uttarakhand, Himachal Pradesh, Bihar, Jammu and Kashmir, West Bengal, Chhatishgarh and Sikkim. In Madhya Pradesh, the barley crop is grown in an area of 85000 ha with a production 110,000 tonnes and productivity of 1299 Kg/ha.
Systematic and more intensive efforts were made from 1967-68 through AICRP on Barley. Since then number of cultivars were evolved and released for cultivation by farmers. However, these cultivars evolved for higher yield for different regions needs testing for their suitability in different regions.
Proper amount of fertilizer is important for the cultivation of any crop because without inorganic fertilization, the desired production cannot be obtained. Sulphur ranks the fourth major nutrient of plants because it is important constituent of various compounds. Sulphur deficiency in crops has become wide spread in India (Scherer, 2001) [5]. Earlier, with fertilizers like ammonium sulphate and single super phosphate, the S requirement of crops were met. Over the last two decades, there has been a fundamental shift in the S balance towards deficit in agricultural systems for several reasons. In intensive crop rotations, including oil seed crops, S uptake can be very high, especially when the crop residue is removed from the field along with the product. This leads to considerable S depletion in soil if the corresponding amount of S is not applied through fertilizer. It has been reported that in India, more than 41% of soils are deficient in S (Singh, 2001) [6]. The full potential of the crop variety cannot be realized if the deficiency it not corrected (Eppendorfer, 1971) [3].
Efforts are, therefore, needed in recommending proper variety and level of sulphur. The present experiment was conducted to find out proper level of sulphur for better performance of barley varieties under limited irrigated conditions.

Material and Methods
An experiment was conducted at ITM University, Gwalior, Madhya Pradesh on response of barley (*Hardium vulgare* L.) varieties to different levels of sulphur during rabi season of 2015-16. Three varieties (Super laxmi, NDB 2 and NDB 1173) and four levels of sulphur (0, 10, 20 and 30 kg ha^{-1}) were tried in split plot design with three replications. The varieties were tried in main plots and sulphur levels in sub plots. The experiment site falls under humid sub-tropical climate and located in between 23^0 10' N latitude and 79^0 54' E longitudes at an elevation of 411.98 meters above mean sea level.

The soil type of experimental field was sandy loam in nature with pH of 7.4 and EC 0.29 dsm-1, having 242 kg available nitrogen, 20.5 kg available phosphorus, 456 kg available potassium, 8.1 kg available sulphur per hectare. During the crop growth period the maximum temperature varied between 18.9 ºC in January third week to 40.1 ºC in April first week and minimum temperature ranged from 3.9 ºC in third week of December to 23 ºC in second week of April. All other crop management practices except levels of sulphur and varieties were uniformly done in all the treatments.

The crop was sown at a spacing of 22 cm × 10 cm on Nov 11, 2015 and harvested on April 24, 2016. A common level of N, P and K of 80, 50 and 50 kg ha $^{-1}$ was applied to the crop. Ten tons of manure was applied to the field uniformly before ploughing. All the fertilizers were applied at the time of sowing except Nitrogen. Nitrogen was applied in three splits - 50% at the time of sowing and the rest 50% in two equal parts at one month interval. The sulphur was applied as per treatments at sowing in the form of granular Sulpher.

The data were recorded in each treatment excluding border plants in each replication. The data on plant height was recorded on five plants which were tagged randomly in each treatment and in each replication. The observations on numbers of tiller per meter row length and yield attributes-number of effective tiller per meter row length, ear head length (cm), number of grains per ear head, 1000 grain weight, biological yield, grain yield and straw yield were recorded.

The harvested produce from each net plot was tied separately into bundles, air-dried and dry weight of bundles was recorded with the help of spring balance in kilogram. The grain and straw yields were recorded as per standard procedure.

The Harvest Index; the ratio of economic yield to the biological yield was calculated and expressed in per cent age as given below

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (grain yield)}}{\text{Biological yield (grain + straw)}} \text{ X } 100$$

The data obtained on various observations were subjected to statistical analysis by using the techniques of the analysis of variance (ANOVA) and the treatment was tested by F test and Critical difference (CD) at 5% level of significance (Panse and Sukhatme, 1989) [4] for each character to compare the differences among treatment means.

Results and Discussion

Results

Varieties

At harvest, the variety NDB-2 record significantly higher plant height over super laxmi and the plant height of NDB-2 was comparable with NDB-1173 (Table 1). On the other hand, the tiller number at harvest of Super laxmi and NDB-1173 was comparable with each other and significantly superior over NDB-2. At harvest, dry matter and effective tillers recorded with super laxmi was significantly greater than that of NDB-1173 and NDB-2. The dry matter observed in latter two verities was comparable with each other.

The variety super laxmi recorded significantly higher spike length, 100 grain weight and lower number of grains per spike over other two verities NDB-1173 and NDB-2. The spike length and 1000 grain weight in latter two verities was comparable with each other. The variety NDB-2 recorded significantly higher number of spike lets over NDB-1173. The number spike lets per spike observed in latter variety was comparable with that of super laxmi (Table 2)

The varieties super laxmi recorded significantly higher grain yield over that of NDB-1173 and NDB-2 (Table 3). The grain yield in latter two varieties was comparable with each other. The straw yield of super luxmi was significantly greater than that of NDB-2 and comparable with that observed with NDB-1173. The biological yield was significantly higher with super laxmi and variety NDB-2 and was comparable with variety NDB1173The straw yield and biological yield observed in latter two varieties was statistically at par with each other.

The harvest index was higher in variety super laxmi and it was followed by NDB-1173 and NDB-2 (Table 3).

Sulphur levels

At harvest, the plant height increased significantly from 0 to 10 and 20 kg ha^{-1}. However, the plant height observed with 20 and 30kg sulphur ha^{-1} was comparable (Table 1). At harvest, the tiller number observed with 30 kg sulphur per ha^{-1} significantly higher over that of 10 and 20 kg sulphur per ha. The tiller number in latter two levels was significantly higher over that of 0 kg per ha^{-1}.

At harvest, sulphur application at 30 kg per ha^{-1} resulted significantly higher dry matter over 20 kg per ha^{-1} (Table 1). The dry matter observed with latter level of sulphur was significantly greater over that of 10 kg per ha^{-1} and zero sulphur application. The effective tillers and spike length were significantly higher with application of 10, 20 and 30 kg sulphur per ha^{-1} over that of no sulphur application. The spike length in the former three levels of sulphur was comparable.

The application of 30 kg sulphur ha^{-1} has recorded significantly greater number of spikelets per spike as compared to 10 and 20 kg of sulphur ha^{-1} (Table 2). The number of spikelets observed in the latter two levels of sulphur was comparable with each other and significantly superior over 0 level of sulphur. With increase in sulphur levels from 0 to 10 and 20 kg ha^{-1}, there was an increase in grain number/spike. The grain number recorded with application of sulphur at 20 kg ha^{-1} was comparable with that observed at 30 kg sulphur ha^{-1} (Table 2).

The grain yield was significantly higher with application 30 kg sulphur ha^{-1}. over no sulphur application and it was comparable with 10 and 20 kg sulphur ha^{-1}. The grain yield observed in latter two levels of sulphur was comparable with each other and significantly superior over o kg sulphur (Table 3). The straw yield was significantly higher with 30 kg sulphur application over 0 and 10 kg sulphur ha^{-1} and was comparable with that of 20 kg sulphur ha^{-1}. The straw yield observed in latter three levels was comparable with each other.

Application on of sulphur at 30 kg ha^{-1} significantly increased the biological yield over that of 0 and 10 kg ha^{-1}, and it was comparable with 20 kg sulphur ha^{-1} (Table 3). The biological yield observed in latter three levels of sulphur was comparable with each other. Maximum HI was recorded with application of sulphur at 30 kg ha^{-1} which was followed by 20kg ha^{-1}, 10 kg ha^{-1} and 0 kg sulphur ha^{-1}.

Discussion

Varieties

Variety Super laxmi recorded significantly higher yield over NDB -1173 and NDB 2. The grain yield of latter two varieties was comparable with each other (Table 3). The growth parameters like number of leaves per culm, dry matter

production and effective tillers were significantly greater in Super luxmi over other two varieties (Table 1). Similarly, the yield attributing characters like Spike length and 1000 grain weight was higher in super laxmi variety (Table 2). The greater values of growth and yield attributes in Super laxmi variety has resulted significant increase in grain yield over NDB-2 and NDB -1173. Further, these characters had positive correlation with grain yield indicating that any increase in yield attributes and growth result in increased grain yield (Table 4).

Sulphur levels

Significantly higher grain yield was obtained with application of sulphur at 30 kg ha^{-1} as compared to 0, kg ha^{-1} (Table 3). However the grain yield observed with 20 kg sulphur ha^{-1} was on par with that of 30 kg and 0 and 10 kg sulphur ha^{-1}. In the present study, yield and yield components were significantly affected by sulphur application. It might be due to increased levels of sulphur application results in greater concentration of sulphates in plants which could help the plants to produce higher dry matter (Yesim Togay *et al.* 2008) [9] and higher number of fertile tillers $plant^{-1}$, spikelets $spike^{-1}$ and 1000-grain weight. Significantly lower yield was obtained in crop that received 0 kg S ha^{-1} can be attributed to lower values of the above-mentioned characters. Further, the grain yield had positive correlation with growth and yield attributing parameters (Table 4) indicating that improvement in yield attributes and growth in the crop that received higher levels of sulphur resulted in higher grain yield.

Sutaliya *et al.* (2003) [8] stated that the highest grain yield was obtained from 45 kg S ha^{-1} application in barley. Garcia *et al.* (1998) reported that the sulphur based fertilizers increased the yield.

Plant height is an important morphological character directly linked with the productive potential of plant in terms of grain yield. In the present investigation, significantly lower plant height was noticed under lower levels of sulphur (Table 1). Numbers of total and fertile tillers $plant^{-1}$ are also important characters, which ensures higher yield. At low levels of sulphur, reduced numbers of tillers and effective tillers plant-1, spike length, spikelets per spike (Tables 2) were observed. Total dry matter influences yield components. Application of higher levels of sulphur has improved the dry matter of barley (Table 2). The lowest plant height was obtained from the control plots, where as the highest values were obtained from the plots given 30 kg S ha^{-1} (Table 1). A similar trend in growth parameters, yield attributes of barley was reported by other researchers which corroborates the findings of the present study.

The lowest biological yield was obtained with 0 kg S ha^{-1} and the highest biological yield was obtained from 30 kg S ha^{-1}. Withers *et al*. (1997) reported that inorganic S application increased straw yield of cereals by 34%.

It has been reported that an increase of sulphur rates tended to increase the content of sulphates in plants especially in the juvenile growth phase and following the application of $S\text{-}SO_4$. The maximum dose of sulphur results in its higher uptake there by the yield (Skwierawska *et al.*, 2008) [7]. Further, optimium use of fertilizers containing sulphur improves utilization of nutrients, especially nitrogen. Favourable influence of nitrogen metabolism and mutual interactions between these two elements were reported by Fismes *et al.* (2000). Skwierawska *et al.* (2008) [7] reported that application of sulphur had significant stimulating effect on the yields of grain and straw of spring barley compared to the NPK fertilizer alone. Sulphur based fertilizers decrease the pH of soil and increases the uptake of other plant nutrients thereby yield increases.

From this study, it can be concluded that growing of barley variety Super luxmi with 30 kg S ha^{-1} gives higher yield in gird region of northern Madhya Pradesh.

Table 1: Effect varieties and sulphur levels on plant height at harvest, effective tillers, number of tillers of barley

Varieties	Plant height at harvest, cm	Effective tillers, Number m length	Tiller number Per m row length at harvest
NDB-1173	93.50	67.83	89.96
NDB-2	95.66	66.70	86.15
Super laxmi	88.28	72.77	91.22
S.Em.±	1.43	1.22	1.27
CD at 5%	4.09	3.62	3.61
Sulphur Levels, $kgha^{-1}$			
0	81.90	60.22	81.06
10	87.07	69.56	86.34
20	99.23	72.22	89.49
30	101.71	74.40	99.55
S.Em.±	1.89	1.50	1.27
CD at 5%	5.31	5.89	3.61
Varieties and Sulphur level			
S.Em.±	16.00	12.74	10.77
CD at 5%	-	-	-

Table 2: Effect varieties and sulphur levels on spike length, number of grains per spike, number of spike lets per spike and 1000 grain weight of barley

Varieties	Spike length (cm)	Number of grains/spike	Number of Spikelet /Spike	1000 grain Weight (g)
NDB-1173	7.44	47.69	57.53	43.00
NDB-2	7.62	48.74	58.23	41.61
Super laxmi	7.02	46.18	55.78	48.75
S.Em.±	0.11	0.55	0.16	0.84
CD at 5%	0.33	1.62	0.48	2.51
Sulphur Levels, kg/ha^{-1}				
0	6.80	44.61	53.72	44.82

10	7.37	47.10	57.37	43.95
20	7.47	48.86	57.74	44.45
30	7.80	49.58	59.89	44.63
S.Em.±	0.16	0.38	0.44	0.89
CD at 5%	0.63	1.19	1.73	NS
Varieties and Sulpher lev1el				
S.Em.±	1.36	3.19	3.74	7.57
CD at 5%	-	--	-	-

Table 3: Effect varieties and sulphur levels on grain yield (Kg ha^{-1}), straw yield (kg ha^{-1}) and biological yield (kg ha^{-1}) of barley

Varieties	Grain Yield Kg ha^{-1}	Straw yield Kg ha^{-1}	Biological yield kg ha^{-1}	Harvest Index (%)
NDB-1173	2651	3506	6157	35.24
NDB-2	2590	3179	5769	35.99
Super laxmi	3016	3636	6652	36.30
S.Em.±	75	145	220	-
CD at 5%	223	429	652	-
Sulphur Levels, kg/ha^{-1}				
0	2532	3136	5668	34.17
10	2602	3328	5930	34.95
20	2782	3460	6242	36.36
30	3090	3837	6927	37.90
S.Em.±	99	108	207	-
CD at 5%	389	425	814	-
Varieties and Sulpher lev1el				
S.Em.±	840	918	1758	-
CD at 5%	-	-	-	_-

Table 4: Correlation between grain yield and growth and yield attributes

S/N	Character.	Calculated Correlation values
1	No. of grain / spike	0.24
2	Number of spikelet per spike	0.36 *
3	Number of tiller per meter at harvest	0.50 *
4	Dry weight per plant at harvest	0.48 *
5	Number of leaves per plant at 60 DAS	0.48 *
6	Plant height at harvest	0.38 *
7	Straw yield, kg/ha	0.33 *

Value at 34 df at 5% = 0.326 *significant at 5% level

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