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Research Article

Response of malt barley (*Hordeum vulgare* L.) varieties to nitrogen and sulphur application under Agro-climatic zone IIIa (semi-arid eastern plain zone) of Rajasthan

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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 (Bold and Thin grain (%), Hectoliter weight (kg hl^{-1}). In case of nitrogen and sulphur applications, chlorophyll content (%) at flag leaf stage and flag leaf area (cm), grain and straw yield (q ha^{-1}), Nitrogen and Sulphur content (%) in grain and straw and bold and thin grain (%) and hectoliter weight (kg hl^{-1}) of barley were improved. The highest chlorophyll content (%) at flag leaf stage and flag leaf area (cm), grain and straw yield (kg hl^{-1}), Nitrogen and Sulphur content (%) in grain and straw and bold, thin grain (%) and hectoliter weight (kg hl^{-1}) 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: Barley varieties, nitrogen, sulphur, yield, quality

1. 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). 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). 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).

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). It is the most important growth limiting factor in non-legumes (Zebarth *et al.* 2009).

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 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 (0.0-0.15 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 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 120 kg ha^{-1} (N3) and three sulphur levels 0 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 15^{th} and 19^{th} 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 tagged for required measurements. After harvesting, 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. After threshing and winnowing, grain yield per plot was weighed and expressed in terms of q ha^{-1}. Straw yield was obtained by subtracting the grain yield per plot from the respectively biological yield $plot^{-1}$ and expressed in terms of q ha^{-1}. Chlorophyll content at flag leaf stage analysed by collecting fresh leaf samples from the crop. These samples were immediately taken to lab, washed with distilled water and dried with blotting paper. A sample of 100 mg was grinded well in mortal and pestle with 80 percent acetone and spell in a 25 ml volumetric flask. The volume was raised up to the mark and absorbance was recorded at 645-663 nm using spectrophotometer. The chlorophyll content was computed by following formula,

(mg/g fresh weight of leaf)

$$= \frac{20.2(A\ 645) + 8.02\ (A663) X\ V}{a \times 1000 \times W}$$

Where, a = Length of light path in cell (1 cm)

V = Volume of extract and

W = Weight of leaf sample

Flag leaf area was recorded in cm^2 by measuring the maximum length and width and multiplied by multiplication factor (K= 0.64) as per method described by Sestak *et al.*, 1971. After threshing and winnowing, grain yield per plot was weighed and expressed in terms of q ha^{-1}. Straw yield was obtained by subtracting the grain yield per plot from the respectively biological yield $plot^{-1}$and finally expressed in terms of q ha^{-1}. Bold and Thin grain (%) samples of grain were taken replication wise to record the bold and thin grain in percent. The sortimat machine were used to separates bold and thin grain. Proportion of bold grain and thin grain determine through sieving from 2.5 mm sieve and 2.2 mm sieve respectively. For hectolitre weight (kg/hl), samples of grain were taken replication wise to record the test weight in kilogram per hectolitre. The hectolitre weight apparatus used to measure test weight in kilogram per hectolitre. malting and mashing. The nitrogen content in grain and straw drawn at the time of threshing and winnowing were ground and analysed. Nitrogen was estimated by digesting the samples with sulphuric acid using hydrogen peroxide to remove black colour. Estimation of nitrogen was done by colorimetric method using Nessler's reagent to develop colour (Snell and Snell, 1949). Nitrogen content was calculated and expressed in percentage. Similarly, estimation of sulphur was done by Turbimetric method (Tabatabai and Bremmener, 1970). 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).

3. Results and discussion

3.1. Chlorophyll content at flag leaf stage and flag leaf area

Data regarding chlorophyll content at flag leaf stage and flag leaf area as affected by different treatments (Table 1) revealed that varieties did not cause any significant variation in chlorophyll content at flag leaf stage and flag leaf area during both the years of experimentation and in pooled data. However, nitrogen application of 120 kg N ha^{-1} recorded the significantly highest chlorophyll content at flag leaf stage and flag leaf area over 90 kg N ha^{-1} and control during both the years of experimentation as well as in pooled analysis. The increase in chlorophyll content at flag leaf stage by 120 kg N ha^{-1} was 6.07 and 20.24 per cent over 90 kg N ha^{-1} and control, increase in flag leaf area by 120 kg N ha^{-1} was 4.73 and 13.90 per cent over 90 kg N ha^{-1} and control, respectively. It can be ascribed to the better nutritional environment in root zone for growth and development of crop as well as in plant system. Amongst nutrients, N and P are considered to be the most important for exploiting genetic potential of crop. The overall improvement in growth of crop with the addition of higher nitrogen could be ascribed to its pivotal role in several physiological and biochemical processes which are of vital importance for development of the plants. Nitrogen is considered one of the indispensable mineral nutrients for growth and development of plants, as it is the basis of fundamental constituents of all living matters (Blumental *et al.,* 2000). Sulphur application bought significant variation in chlorophyll content and

Table 1 Response of malt barley varieties to nitrogen and sulphur on chlorophyll content at flag leaf stage and flag leaf area (cm)

Treatments	Chlorophyll content (%)			Flag leaf area (cm)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Varieties						
RD 2668	2.70	2.73	2.72	24.34	28.19	26.26
DWRUB 52	2.73	2.78	2.75	24.67	28.46	26.57
RD 2849	2.75	2.80	2.77	24.86	28.67	26.76
SEm±	0.02	0.03	0.02	0.22	0.19	0.15
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Nitrogen levels (kg/ha)						
60	2.48	2.47	2.47	22.73	26.60	24.67
90	2.73	2.87	2.80	24.85	28.81	26.83
120	2.97	2.97	2.97	26.29	29.90	28.10
SEm±	0.02	0.03	0.02	0.22	0.19	0.15
CD (P=0.05)	0.07	0.07	0.05	0.64	0.54	0.41
Sulphur levels (kg/ha)						
0	2.51	2.59	2.55	22.87	26.88	24.88
10	2.78	2.81	2.80	24.92	28.92	26.92
20	2.89	2.91	2.90	26.08	29.52	27.80
SEm±	0.02	0.03	0.02	0.22	0.19	0.15
CD (P=0.05)	0.07	0.07	0.05	0.64	0.54	0.41

NS = Non significant

Table 2: Response of malt barley varieties to nitrogen and sulphur on grain and straw yield

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

flag leaf area at flag leaf stage (Table 1). Application of 20 kg S ha^{-1} recorded the highest chlorophyll content and flag leaf area proved significantly superior over 10 kg S ha^{-1} and control during both the years of experimentation as well as in pooled analysis by 3.5 and 13.72 per cent in chlorophyll content and 3.20 and 11.73 per cent in case of flag leaf area, respectively. This might be due to the fact that application of S improves not only the availability of sulphur but also other nutrients which are considered vitally important for the growth and development of plants (Gupta and Sehnug, 2000).

3.2. Barley Yield

Barley varieties differ significantly in the grain and straw yield during both the year of experiment and on pooled data (Table 2). 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. Chakrawarty 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. 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 2). 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) in barley and Jat *et al.* (2014) in wheat. Sharma and Verma (2010) 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.

3.3. Quality parameters

3.3.1. Bold and Thin grain (%)

A critical examination of data (Table 3) revealed that significant variation in bold and thin grain was recorded due to different varieties. The variety RD 2849 had significantly higher bold grains as compared to DWRUB 52 and RD 2668 varieties during individual years and in pooled analysis. However, the variety RD 2849 had significantly lowest thin grain as compared to the varieties DWRUB 52 and RD 2849 during individual years and in pooled data. 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

Table 3: Response of malt barley varieties to nitrogen and sulphur on bold, thin grain and hectoliter weight

Treatments	Bold grain (%)			Thin grain (%)			Hectoliter weight (kg hl^{-1})		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
Varieties									
RD 2668	83.96	84.99	84.48	2.36	2.23	2.29	57.20	58.15	57.72
DWRUB 52	86.60	88.31	87.45	1.70	1.61	1.65	58.89	59.66	59.27
RD 2849	93.04	93.86	93.45	0.84	0.80	0.82	63.49	64.76	64.12
SEm±	0.58	0.77	0.48	0.01	0.01	0.01	0.54	0.52	0.38
CD (P=0.05)	1.66	2.18	1.35	0.04	0.04	0.03	1.54	1.47	1.05
Nitrogen levels (kg/ha)									
60	83.41	84.27	83.84	2.17	1.98	2.08	56.06	57.02	56.54
90	89.40	90.80	90.10	1.97	1.89	1.93	61.36	62.43	61.90
120	90.79	92.09	91.44	0.76	0.77	0.76	62.14	63.21	62.68
SEm±	0.58	0.77	0.48	0.01	0.01	0.01	0.54	0.52	0.38
CD (P=0.05)	1.66	2.18	1.35	0.04	0.04	0.03	1.54	1.47	1.05
Sulphur levels (kg/ha)									
0	84.81	85.15	84.98	2.04	1.97	2.01	57.84	58.96	58.40
10	89.24	90.13	89.69	1.90	1.85	1.88	60.28	61.58	60.93
20	89.55	91.88	90.72	0.96	0.82	0.89	61.45	62.12	61.79
SEm±	0.58	0.77	0.48	0.01	0.01	0.01	0.54	0.52	0.38
CD (P=0.05)	1.66	2.18	1.35	0.04	0.04	0.03	1.54	1.47	1.05

NS = Non significant

Table 4: Response of malt barley varieties to nitrogen and sulphur on Nitrogen and Sulphur content in grain and straw

Treatments	N content (%)				S content (%)			
	Grain		Straw		Grain		Straw	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Varieties								
RD 2668	1.58	1.59	0.685	0.706	0.157	0.159	0.096	0.097
DWRUB 52	1.60	1.62	0.689	0.712	0.159	0.161	0.097	0.100
RD 2849	1.61	1.63	0.692	0.715	0.160	0.162	0.097	0.101
SEm±	0.01	0.01	0.006	0.005	0.001	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Nitrogen levels (kg/ha)								
60	1.48	1.49	0.623	0.647	0.150	0.153	0.093	0.094
90	1.63	1.67	0.717	0.739	0.161	0.164	0.098	0.100
120	1.66	1.69	0.725	0.748	0.164	0.167	0.099	0.102
SEm±	0.01	0.01	0.006	0.005	0.001	0.001	0.001	0.001
CD (P=0.05)	0.04	0.03	0.018	0.015	0.004	0.004	0.002	0.003
Sulphur levels (kg/ha)								
0	1.52	1.55	0.635	0.661	0.152	0.154	0.092	0.094
10	1.62	1.64	0.710	0.731	0.160	0.163	0.098	0.101
20	1.64	1.66	0.721	0.741	0.163	0.166	0.100	0.102
SEm±	0.01	0.01	0.006	0.005	0.001	0.001	0.001	0.001
CD (P=0.05)	0.04	0.03	0.018	0.015	0.004	0.004	0.002	0.003

NS = Non significant

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. In another 3 year study, DWR 28 (2-row malt barley variety) found to be superior over check BCU 73 in yield as well as in malt quality parameters (Anonymous 2004). Among of nitrogen levels, application of 120 kg N ha^{-1} recorded the highest bold grain 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 bold grain of barley by 9.06 and 7.46 per cent as compared to control, respectively, in the pooled data. Data about thin grain revealed that nitrogen bought significant variation in thin grain during both the years of experimentation as well as in pooled analysis. Among of nitrogen levels application of 90 kg N ha^{-1} recorded significantly lowest thin grain by 7.78 per cent as compared to control, respectively, during both the years of experimentation as well as in pooled analysis.

Sulphur also bought significant increase in bold grain during both the years of experimentation as well as in pooled analysis. Among of sulphur levels application of 20 kg S ha^{-1} recorded the highest bold grain 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 Sulphur increased the bold grain of barley by 6.75 and 5.54 per cent as compared to control, respectively, in pooled data. However, application of 10 kg S ha^{-1} recorded the lowest thin grain by 6.90 per cent as compared to control, respectively, during both the years of experimentation as well as in pooled analysis. Sulphur applications also significantly increased the concentration of S-methyl methionine (the precursor of dimethyl sulphide) in kilned malt, which could impact on beer flavor (Zhao *et al.* 2006).

3.3.2. Hectoliter weight (kg hl^{-1})

The variety RD 2849 had significantly highest hectoliter weight as compared to DWRUB 52 and RD 2668 varieties during individual years and in pooled data. Data revealed that nitrogen bought significant increase in hectoliter weight during both the years of experimentation as well as in pooled analysis (Table 3). Application of 120 kg N ha^{-1} recorded the highest hectoliter weight 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. On the basis of pooled data, application of 120 kg and 90 kg N ha^{-1} increased the hectoliter weight of barley by 10.85 and 9.48 per cent as compared to control, respectively. Among of sulphur levels application of 20 kg S ha^{-1} recorded the highest hectoliter weight and proved 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. On the basis of pooled data application of 20 kg and 10 kg S ha^{-1} increased the hectoliter weight of barley by 5.80 and 4.33 per cent as compared to control, respectively. Increase in bold grain percent and hectoliter weight indicate significantly increase in malt yield, malt friability, malt homogeneity and hot water extract.

3.3.3. Nitrogen and Sulphur content in grain and straw

Different treatments of varieties failed to cause significant variation in nitrogen and sulphur content in grain and straw of barley during both years of research and in pooled data (Table 4). The highest N content in grain and straw was observed with 120 kg N ha^{-1} during individual years as well as in pooled data and was found significantly superior over control and at par with 90 kg N ha^{-1}. On the basis of pooled data, the significantly increased in N content of grain and straw due to 120 kg N ha^{-1} was 12.75 and 16.06 per cent in grain and straw, respectively over control. Similarly, highest S content in grain and straw was observed with 120 kg N ha^{-1} during individual years as well as in pooled data which was found significantly superior over control and was at par with 90 kg N ha^{-1}. On the basis of pooled data the increase in S content in grain and straw due to 120 kg N ha^{-1} was 9.27 and 7.44 per cent in grain and straw, respectively over control. The highest Nitrogen content in grain and straw was observed with 20 kg S ha^{-1} during individual years as well as in pooled data which was found significantly superior over control and was at par with 10 kg S ha^{-1}. On the basis of pooled data, the significantly increased in N content of grain and straw due to 20 kg S ha^{-1} was 7.14 and 12.80 per cent in grain and straw, respectively over control. Similarly, highest S content in grain and straw was observed in 20 kg S ha^{-1} during individual years as well as in pooled data which was found significantly superior over control and was at par with 10 kg S ha^{-1}. On the basis of pooled data the increase in S content in grain and straw due to 20 kg S ha^{-1} was 7.44 and 8.60 per cent in grain and straw, respectively over control. This might be due to low initial available sulphur status of soil and sulphur content may be attributed to increased availability of nutrients in plots receiving S due to conducive environment in rhizosphere and solubilization of nutrients in the soil leading to higher absorption by the plants.

4. References

1. Anonymous. 2004. Progress report: All India coordinated wheat and barley improvement project. Directorate of Wheat Research, Karnal, Haryana, India. pp. 4.11
2. Baik BK and SE Ullrich. 2008. Barley for food: Characteristics, improvement, and renewed interest. *Journal of Cereal Science* **48**: 233–42.
3. Blumenthal JM, DD Baltensperger, DR Shelton, LA Nelson, GD Binford and S Geleta. 2000. Nitrogen and variety effects in winter wheat, Abstracts of the Third International Crop Science Congress, Hamburg, Germany.
4. Chakrawarty VK and KP Kushwaha. 2007. Performance of barley (Hordeum vulgare) varieties under sowing dates and nitrogen levels in Bundelkhand. *Progressive Research* **2**: 163-64.
5. Chhonkar PK and RK Rattan. 2000. Soil Fertility Management for Sustainable Agriculture. *Indian Farming* **49**(11): 26-31.
6. Fisher RA and F Yates. 1963. Statistical tables. Oliver and Boyd, Edinburgh, London.
7. Gupta AK and E Schnug. 2000. Physiological, agronomic, horticultural and industrial aspects of Sulphur nutrition in Plants. *Annals Agriculture Bio Research.* **12**: 121-123.
8. Jat SL, V Nepalia, J Choudhary and D Singh. 2014. Effect of nitrogen and weed management on productivity and quality of durum wheat (*Triticum durum*). *Indian Journal of Agronomy* **59** (2): 281-285.
9. Katiyar AK and SK Uttam. 2007. Effect of fertility levels and weed control measures on growth, yield attributes and yield of barley (*Hordeum vulgare* L.) under rainfed condition. *Bhartiya Krishi Anusandhan Patrika* **22**: 324-326.
10. Pal D, S Kumar and RPS Verma. 2012. Pusa Losar (BHS 380) – the first dual- purpose barley variety for northern hills of India. *Indian Journal of Agricultural Sciences* **82**: 164 -165.
11. Panse VG and PV Sukhatme. 1985. "Statistical Methods for Agricultural Workers". *Indian Council of Agricultural Research*, New Delhi.
12. Pourkheirandish M and T Komatsuda. 2007. The importance of barley genetics and demonstration in a global perspectives. *Annals of Botany* **100**: 999– 1008.
13. Sardana V and GP Zhang. 2005. Genotypic variation in some quality traits of malt barley (*Hordeum vulgaer L.*) caused by time of nitrogen application and kernel position within spike. *Cereal Research Communications* **33**: 817-823.
14. Sestak Z, J Catsky and PG Jarvis. 1971. Plant photosynthetic production: Manual of methods. Dr. W.junk N.V. Publishers, Den Haag.
15. Sharma RK and RPS Verma. 2010. Effect of irrigation, nitrogen and varieties on the productivity and grain malting quality in barley. *Cereals Research Communication* **38**: 419-28.
16. Snell FB and CT Snell, 1949. *Colorimetric Method of Analysis.* IIAD Vannostrand Co., New Delhi.
17. Tabatabal MA and JM Bremmer. 1970. A turbimetric method of determining Sulphur in plant materials. *Agronomy Journal* **62**: 806-808.
18. Verma RPS, AS Kharub, D Kumar, B Sarkar, R Selvakumar, R Singh, R Malik, R Kumar and I Sharma. 2011. Fifty years of coordinated barley research in India. Directorate of Wheat Research, Karnal-132001. Research Bulletin No. **27**: 46.
19. Zebarth BJ, WJ Arsenault, S Moorehead, H TapaniKunelius and M Sharifi. 2009. Effect of fertilizer nitrogen management and plough-sown date for Italian ryegrass on soil nitrogen supply to a subsequent potato crop. *Agronomy Journal* **101**:1573-1580.
20. Zhao FJ, S Fortune, VL Barbosa and P Robson. 2006. Effect of Sulphur on yield and quality of barley. *Journal of Cereal Sciences* **3** (3): 369-377.