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Influence of sowing times, seed rates and row spacings on physiological studies of barley (*Hordeum vulgare* L.)

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Abstract
The field experiment was conducted at the Regional Research Station (Bawal) Department of Agronomy, CCS Haryana Agricultural University, Hisar (India) during the year 2015-16 and 2016-17. To evaluate the optimum sowing time, seed rate and row spacing on physiological studies of barley. The experiment was conducted with split-split plot design replicated three times. Treatments consisted of four dates of sowing *viz;* D_1 (last week of October), D_2 (1st week of November), D_3 (2nd week of November) and D_4 (3rd week of November) and two seed rates *viz;* recommended and 110% of recommended was kept as main plot and three row spacings *viz;* (17.5 cm), (20 cm) and (22.5 cm recommended) was kept as sub plot. The received results that physiological studies *viz;* LAI, LAD, CGR, NAR and RGR were significantly enhanced under D_1 (last week of October) sown crop than other sowing dates. Physiological studies were significantly superior under (20 cm) row spacing over the rest row spacing and not significant effects of that two seed rates. The worthier physiological studies were figures under D_1 (last week of October) with (20 cm) row spacing.

Keywords: Sowing times, seed rate, row spacing, physiology, barley

1. Introduction
Barley (*Hordeum vulgare* L.) is an important cereal crop after wheat, rice and maize in the world and third important cereal after rice and wheat in India. Barley requires less water and can be cultivated in areas where irrigation water is not easily available. It grows successfully in a wider range of climatic conditions than any other cereals (Hales1992) [4].

Cultivation trend of barley is declining among Haryana farmers due to lack of high yielding varieties as well as management practices like appropriate sowing time as they prefer to sow barley under late sown conditions. Matching the phenology to the prevailing weather conditions is the single most important factor to maximize the yield of barley. Very early planting may expose the crop to higher temperature at tillering stage while late planting may result in low biomass production and poor grain development due to higher temperature conditions at the time of maturity (Ram *et al.* 2010) [11].Under late sown conditions, barley face low temperature in the earlier part and high temperature in the later part of the growing season and require favourable moisture for better growth and development. About 80 per cent of the barley crop cultivated at late sowing condition after harvesting the transplanted rice and this problem will be further increased due to global warming. In spite of low yield of barley due to post anthesis heat stress, cultivation of barley cannot be avoided totally. Therefore, efforts ought to be made to minimize the effect of temperature variation caused due to changed sowing date by choosing appropriate barley varieties which can synchronize its temperature requirement (Alam *et al.* 2013) [1].

Plant density is one of the major factors determining the ability of the crop to capture resources; it is of particular importance that it is being under fairly close control by the farmers in most barley cultivation. There has been interest in defining the relationships between density and crop yield quantitatively in order to establish optimum populations and maximum attainable yields under various situations (Hussain *et al.* 2010) [5].

Optimal row spacing is one of several important agronomic approaches that can be used to enhance barley yield by optimizing tillering capacity and the efficient utilization of other available resources (Thorsted *et al.* 2006 [15] and Hussain *et al.* 2014) [8]. Row spacing regulates crop productivity by changing the plant architecture, photosynthetic efficiency of leaves and source–sink relations of field crops (Samani *et al.* 1999) [13].

So, an experiment was planned to study the influence of sowing times, seed rates and row spacings on physiological studies of barley under Haryana conditions.

2. Materials and Methods

The field experiment was conducted at Regional Research Station of Chaudhary Charan Singh Haryana Agricultural University, Bawal in *rabi* (winter) season during of 2015-16 and 2016-17. The experimental Site (28º4' N latitude and 76º35' E longitude at an altitude of 266 meters above mean sea level) was having sandy loam soil, low in organic carbon (2.2 g C kg^{-1}) and slightly alkaline (pH 7.5). The region has a tropical and semi-arid climate having cool winters in the crop season.

The experiment was conducted in split-split plot design with four sowing dates *viz;* (Last week of October, 1st week of November, 2nd week of November and 3rd week of November x two seed rates 100% recommended 87.5 kg/ha and 110% of recommended *i.e.* 96.25 kg/ha) as main plot treatments and three row spacing *viz;* (17.5, 20 and 22.5 cm) as sub plot treatments with three replications. The crop was sown were in manually by *pora* method. The total recommended dose applied to the crop was N, P, K = 60: 30: 20 kg ha^{-1} in the form of Urea, Single Super Phosphate and Muriate of potash were applied ½ N+ full P and K at the time of sowing and remaining ½ N after first irrigation. The total rainfall of 21.10 mm and 64.30 mm was received during 2015-16 and 2016-17, respectively.

The crop received three irrigations at 30-35, 65-70 and 90-95 days after sowing in study. The herbicides (Metsulfuron @ 87.5 ml/ha + Pinoxaden @ 10 gm/ha) were applied as tank mix application after first irrigation to control wild oats and other broad leaf weeds. The observations on physiological studies were recorded at the different crop growth stages and the data were analyzed using standard method of ANOVA.

3. Results and Discussion

3.1 Effect of sowing dates

The various physiological parameters *viz*., LAI, LAD, CGR, NAR and RGR were significantly affected by the sowing times (Table 1, 2, 3, 4 and 5). LAI, LAD and CGR were found significantly higher with last week of October sown crop as compared to rest of the sowing times at all the stages in both the years of experimentation. However, 1st week of November sowing also exhibited superiority over rest sowing times with respect to LAI, LAD and CGR at all the stages. It is obvious that plant growth is a function of various environmental factors. Last week of October sowing might have got favourable environment which helped in better growth, photosynthesis and higher dry matter accumulation resulting in higher CGR, NAR and LAD. The NAR and RGR showed differential values at different growth stages (30 and 60 DAS) in both the years.

Table 1: Effect of sowing dates, seed rate and row spacing on Leaf area index at 30, 60 and 90 DAS of barley

Treatments	Leaf area index 2015-16			Leaf area index 2016-17		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Date of sowing						
D_1	1.55	2.58	3.65	1.58	2.62	3.69
D_2	1.53	2.42	3.55	1.54	2.48	3.58
D_3	1.15	2.25	3.42	1.19	2.29	3.44
D_4	0.92	1.88	3.25	0.98	1.94	3.28
S.Em±	0.02	0.05	0.06	0.02	0.05	0.06
CD (P=0.05)	0.07	0.16	0.19	0.08	0.17	0.18
Seed rates						
S_1	1.27	2.23	3.41	1.31	2.30	3.45
S_2	1.30	2.35	3.52	1.33	2.40	3.55
S.Em±	0.01	0.03	0.04	0.01	0.04	0.04
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Row Spacing						
R_1	1.05	1.98	3.24	1.09	2.02	3.28
R_2	1.55	2.57	3.70	1.59	2.64	3.73
R_3	1.25	2.32	3.45	1.28	2.39	3.49
S.Em±	0.02	0.03	0.05	0.07	0.04	0.05
CD (P=0.05)	0.06	0.10	0.17	0.02	0.11	0.17

Table 2: Effect of sowing dates, seed rate and row spacing on Leaf area duration at 30, 60 and 90 DAS of barley

Treatments	Leaf area duration 2015-16			Leaf area duration 2016-17		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Date of sowing						
D_1	23.30	61.98	93.35	23.75	64.88	95.08
D_2	22.85	59.10	89.42	23.05	60.20	90.85
D_3	17.20	51.43	85.53	17.90	52.83	86.58
D_4	13.73	41.95	76.98	14.63	43.73	78.30
S.Em±	0.38	0.86	1.70	0.37	1.31	1.64
CD (P=0.05)	1.16	2.62	5.15	1.14	3.97	4.99
Seed rates						
S_1	18.52	52.03	84.64	19.10	53.54	86.14
S_2	20.01	55.20	88.00	20.56	57.28	89.26
S.Em±	0.27	0.61	1.20	0.26	0.93	1.16
CD (P=0.05)	0.82	1.85	NS	0.80	2.81	NS
Row spacing's						
R_1	15.77	45.33	78.22	16.37	47.73	79.54
R_2	23.31	61.87	94.07	23.85	63.35	95.36
R_3	18.73	53.62	86.86	19.28	55.16	88.20
S.Em±	0.39	0.91	1.57	0.38	1.30	1.86
CD (P=0.05)	1.14	2.65	4.52	1.11	3.75	5.36

At 90 DAS, the values of NAR and RGR were higher under early (D_1 and D_2) date of sowing as compared to delayed (D_3 and D_4) sowing. It might be due to the juvenility of plants at earlier growth periods and shading effects of upper leaves on older ones at later growth stages. The results are in close agreement with the findings of (Shivani *et al.* 2003 [14] and Alam *et al.* 2013) [1].

3.2 Effect of Seed rates

Effect of seed rate management (S_1 and S_2) on all parameter of physiological studies was found non-significant except LAD and NAR (Table 1, 2, 3, 4 and 5) during both the years. The quantitative difference between two seed rates *i.e.,* S_1 (100% recommended seed rate @ 87.5 kg/ha) and S_2 (110% of recommended seed rate @ 96.25 kg/ha) was miniature change of seed rate, therefore, it had no profound effect on above mentioned most of the parameters under study during both the years. Whereas, LAD under S_2 was significantly higher compared to S_1 at 30 and 60 DAS except at 90 DAS. This may be due to dense foliage under S_2 at 30 and 60 DAS as compared to S_1 which may cause increase in leaf area. NAR was significantly higher under S_1 at 60 and 90 DAS except at 30 DAS than that of S_2 during 2015-16. Whereas in 2016-17, values of NAR were higher in S_1 at 30 and 60 DAS except at 90 DAS compared to S_2. The variations in NAR values at different crop stages in different years may be because of variation in dry matter accumulation and leaf area at various crop stages in different years. Appropriate seed rate is most important agronomic management factor in barley. So correct amount of seed is necessary for good crop stand and establishment (Nandi *et al.* 2018) [10]. Similar results reported by Anwar *et al.* (2015) [2], Kaur *et al.* (2015) [9] and Rehmani *et al.* (2016) [12]

Table 3: Effect of sowing dates, seed rate and row spacing on CGR (g/m^2/day) at 30, 60 and 90 DAS of barley

Treatments	CGR (g/m^2/day) 2015-16			CGR (g/m^2/day) 2016-17		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Date of sowing						
D_1	1.65	5.97	19.61	1.75	6.34	21.44
D_2	1.59	5.81	18.04	1.68	6.17	20.20
D_3	1.31	5.26	16.55	1.41	5.36	18.50
D_4	1.04	4.77	11.44	1.10	4.89	12.87
S.Em±	0.02	0.12	0.43	0.03	0.15	0.34
CD (P=0.05)	0.06	0.36	1.32	0.11	0.44	1.05
Seed rates						
S_1	1.39	5.44	16.40	1.48	5.68	18.25
S_2	1.40	5.46	16.42	1.49	5.70	18.26
S.Em±	0.01	0.08	0.30	0.02	0.10	0.24
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Row Spacings						
R_1	1.36	5.37	16.39	1.43	5.62	18.24
R_2	1.43	5.51	16.42	1.53	5.74	18.26
R_3	1.40	5.47	16.41	1.49	5.71	18.25
S.Em±	0.02	0.08	0.30	0.03	0.12	0.32
CD (P=0.05)	NS	NS	NS	NS	NS	NS

3.3 Effect of rows spacing

Row spacings has markedly affected on physiological studies of barley *viz.*, LAI, LAD, NAR and RGR except CGR during the both years show in (Table 1, 2, 3, 4 and 5).

Agronomic management of row spacing at 20 cm had significantly higher values of LAI and LAD over 17.5cm 22.5 cm row spacing at 30, 60 and 90 DAS during both the years. This may be due to more efficiently utilisation of soil moisture during crop growth period under 20 cm row spacing than 17.5 and 22.5 cm row spacing. This beneficial effect of water in maintaining cell turgidity, cell elongation, cell division, photosynthesis, respiration, uptake of water and essential nutrients and translocation of photosynthates may cause increase in leaf area.

Table 4: Effect of sowing dates, seed rate and row spacing on NAR (g/m^2/day) at 30, 60 and 90 DAS of barley

Treatments	NAR (g/m^2/day) 2015-16			NAR (g/m^2/day) 2016-17		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Date of sowing						
D_1	4.77	3.16	6.41	4.91	3.10	6.84
D_2	4.50	2.89	6.17	4.86	3.17	6.79
D_3	4.74	3.22	5.93	4.93	3.23	6.53
D_4	4.46	3.64	4.61	4.52	3.54	5.09
S.Em±	0.11	0.08	0.08	0.09	0.09	0.14
CD (P=0.05)	NS	0.24	0.25	0.28	0.28	0.43
Seed rates						
S_1	4.73	3.35	5.90	4.93	3.36	6.44
S_2	4.51	3.10	5.66	4.67	3.16	6.19
S.Em±	0.07	0.05	0.05	0.06	0.06	0.10
CD (P=0.05)	NS	0.17	0.17	0.20	0.20	NS
Row spacings						
R_1	5.08	3.70	6.38	5.18	3.76	6.93
R_2	3.99	2.76	5.25	4.24	2.78	5.76
R_3	4.78	3.21	5.70	4.99	3.23	6.24
S.Em±	0.11	0.05	0.09	0.09	0.09	0.14
CD (P=0.05)	0.32	0.16	0.26	0.26	0.26	0.40

Table 5: Effect of sowing dates, seed rate and row spacing on RGR (g/g/day) at 30, 60 and 90 DAS of barley

Treatments	RGR (g/g/day) 2015-16			RGR (g/g/day) 2016-17		
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS
Date of sowing						
D_1	0.040	0.051	0.042	0.043	0.052	0.043
D_2	0.043	0.052	0.040	0.043	0.051	0.042
D_3	0.047	0.054	0.042	0.048	0.052	0.044
D_4	0.053	0.057	0.036	0.056	0.059	0.038
S.Em±	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	0.004	0.003	0.003	0.004	0.003	0.003
Seed rates						
S_1	0.046	0.054	0.040	0.048	0.054	0.042
S_2	0.046	0.053	0.040	0.047	0.053	0.042
S.Em±	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Row spacings						
R_1	0.050	0.054	0.040	0.052	0.054	0.042
R_2	0.045	0.053	0.040	0.047	0.052	0.042
R_3	0.043	0.053	0.040	0.044	0.053	0.042
S.Em±	0.001	0.001	0.001	0.001	0.001	0.001
CD (P=0.05)	0.003	NS	NS	0.002	NS	NS

CGR did not vary significantly under different row spacing at all the stages of crop during both the years.

NAR was significantly influenced by agronomic management of row spacing at all crop stages during both the years. R_1 recorded higher values of NAR, followed by R_3 and R_2 at 30, 60 and 90 DAS. Row spacing of 17.5 cm (R_1), 20 cm (R_2) and 22.5 cm (R_3) had no significant effect on RGR at 60 and 90 days of crop stages except at 30 DAS. At 30 days crop stage, R_1 exhibited significantly higher RGR over R_2 and R_3, though the difference between R_2 and R_3 was found at par during both the years.

The variations in NAR values at different crop stages in different years may be because of variation in dry matter accumulation and leaf area at various crop stages in different years. Whereas, the differences in RGR values at various growth stages of crop in different year may be ascribed to differences in dry matter accumulation at different time intervals during crop development in different years. Similar

findings were reported by Hussain *et al.* (2013) [7], Hussain *et al.* (2016) [6] and Gupta *et al.* (2017) [3].

4. Conclusion

In the present study, revealed that all the Physiological parameters were significantly superior under D_1 (last week of October), followed by D_2 (1st week of November), D_3 (2nd week of November) and D_4 (3rd week of November in descending order, increasing seed rate from S_1 @ 87.5 kg/ha to S_2 @ 96.5 kg/ha had no significant effect on the above parameters and Row spacing 20 cm (R_2) was found optimum than other spacings 17.5 cm (R_1) and 22.5 cm (R_3) and (R_2) had higher values of physiological parameters.

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