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Effect of seeding rate on growth and yield of barley (*Hordeum vulgare* L.)

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Abstract
A field experiment was carried out at Agricultural Research Farm, School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh (Punjab) during the *rabi* 2021-22 to study the effect of seeding rate on growth and yield of barley (*Hordeum vulgare* L.). The treatments comprised of two varieties *viz.* DWRUB 52 and PL 426 and four seeding rate *viz.*75, 87.5, 100, 112.5 kg ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. Variety DWRUB 52 produced significantly taller plants (93.91 cm), more tillers per meter row length (83.53), spike per meter row length (118.69), spike length (7.32 cm), test weight (42.13 g) over PL 426 whereas, the variety PL 426 have more grains per spike (42.72), grains weight per spike (1.49 g) over DWRUB 52. However grain yield, straw yield, biological yield and harvest index were significantly higher in variety DWRUB 52 (39.64 q ha^{-1}) than PL 426 (31.97 q ha^{-1}). The 100 kg seed rate ha^{-1} significantly produced taller plant height (94.34 cm), spike length (7.72 cm) over 75 kg seed rate ha^{-1}, whereas 112.5 kg seed rate ha^{-1} produced significantly higher tillers per meter row length (81.83), spike per meter row length (113.27) over the 75 kg seed rate ha^{-1} but at par with 100 kg and 87.5 kg seed rate ha^{-1}. The 75 kg seed rate ha^{-1} have significantly highest test weight (42.08 g), number of grains (34.57) over 112.5 kg seed rate ha^{-1} but at par with 87.5 kg and 100 kg ha^{-1}. Similarly the significant higher grain yield was observed with 112.5 kg ha^{-1} (40.47 q ha^{-1}) than 75 kg (28.67 q ha^{-1}) and 87.5 kg (34.87 q ha^{-1}) seed rate ha^{-1} but at par with 100 kg seed rate ha^{-1} (39.22 q ha^{-1}). The interaction between varieties and seed rate was found to be non-significant in all growth parameters, yield attributes and yield.

Keywords: Barley varieties, seed rates, growth parameters, yield attributes and yield

Introduction
Barley is the fourth largest grain crop globally, after wheat, rice, and corn. Barley belongs to family Gramineae and it is commonly used in breads, soups, stews, and health products, though it is primarily grown as animal fodder and as a source of malt for alcoholic beverages, especially beer. Nutritional attributes of barley contribute to the prevention of numerous metabolite disorders providing antioxidant, anti carcinogenic, anti-inflammatory, and cardio- and neuro-protective effects (Bartlomeiej *et al*., 2011) [4]. In India, barley was grown on 590 thousand hectares area producing 1720 thousand tonnes (Anonymous, 2021a) [3]. But in Punjab, barley was grown on 6.2 thousand hectares area with a production of 23.4 thousand tonnes and average yield of 37.81 quintals per hectare (Anonymous, 2021) [2]. It tolerates adverse conditions such as cold, salt, and low humidity and high temperatures. The varieties and seeding rate play an important role in yield of barley crop. Higher genetic variation between the all characters were moderately (30 to 60%) or low (<20) heritability which indicates that the environmental influence is high on characters. (Sravani *et al*., 2018) [16]. Seeding rate is directly related to canopy expansion and solar radiation interception, thereby strongly influencing the use of environmental resources by changing relative importance of intra and interplant competition for light, water and nutrients during crop development (Ranjan *et al.*, 2016) [14]. Identifying optimum seeding rate for crop varieties is an important agronomic practice to improve the productivity and the quality of the produce. Therefore, this study was conducted to evaluate the effect of seeding rate on the growth and yield performance of barley varieties grown under Punjab conditions.

Materials and Methods
The experiment was carried out during rabi season 2021-22 at the Agriculture Research Farm, School of Agricultural Sciences and Technology, RIMT University, Mandi Gobindgarh, Punjab.

The experimental area located at 30.6642° N latitude and 76.2914° E longitude at an altitude of 268 meters above mean sea level. The site was low in organic carbon (0.38%) and available nitrogen (144.6 kg N ha^{-1}), medium in phosphorus (17.3 kg P_2O_5 ha^{-1}) and potassium (168 kg K_2O ha^{-1}). The treatments comprised of two varieties *viz*. DWRUB 52 and PL 426 and four seed rates *viz*.75, 87.5, 100, 112.5 kg ha^{-1}. The experiment was laid out in randomized complete block design (RCBD) with three replications. The crop was sown with row spacing of 22.5 cm on 4th November 2021 manually with the help of hand ploughing. The 62.5 kg Nitrogen ha^{-1} and 30 kg Phosphorus ha^{-1} is applied in the form of urea (46% N) and DAP (18% N, 46% P_2O_5). The gross plot size 3.5 m × 4.5 m and net plot size was 3.0 m × 4.0 m. The data on growth, yield and yield attributes were collected at specified time of development. The data on plant height at harvest (cm), number of tillers per meter row length, number of spike per meter row length, spike length (cm), test weight (g), number of grains per spike, grain weight per spike (g), grain yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}) and harvest index. Harvest index was obtained by dividing the economical (grain) yield from the biological yield i.e., straw and grain yield. It was calculated for each plot and was represented in percentage.

The formula used to calculate the harvest index was given by Nichiporovich, (1951)

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \text{ X } 100$$

The statistical analysis was done by using the statistical software OPSTAT, 1998 (Sheoran *et al*. 1998) [15].

Results and Discussion

Growth Parameters

Plant height: The plant height of barley was significantly influenced with the varieties and seeding rate. The significantly higher plant height was observed in variety DWRUB 52 (93.91 cm) than PL 426 (86.68 cm) (Table 1).The magnitude of change in plant height was 8.34%. Variation in plant height among varieties may be probably due to their genetic characters. Neelam *et al.,* (2022) [10] also reported that plant height is influenced by varietal difference. The higher plant height was recorded in 100 kg seeding rate ha^{-1} (94.34 cm) than 75 kg seed rate ha^{-1} (84.89 cm) but statistically at par with 112.5 kg seed rate ha^{-1} (92.50 cm) and 87.5 kg seed rate (89.46 cm). It may be due to increased competition for light which increased inter node length, reduced stem thickness, thereby increase plant height but further increasing seeding rate reduce plant height due to inter and intra plant competition for nutrients. Iqbal *et al.,* (2012) [9] concluded that tallest plants (98.33 cm) were observed at seeding rate of 150 kg ha^{-1} while smaller plants (94.33 cm) were recorded at seeding rate of 175 kg ha^{-1} and was statistically similar (94.99 cm) to seeding rate of 125 kg ha^{-1}. Non-significant interaction is found between varieties and seed rate. The interaction between varieties and seed rates for plant height is found to be non-significant.

Number of tillers per meter row length: Number of tillers per meter row length of barley was also significantly influenced by varieties and seeding rate. Among different varieties, the variety DWRUB 52 (83.53) recorded significant higher number of tillers per meter row length over variety PL 426 (72.30) (Table 1). The increase in number of tiller per meter row length of barley variety DWRUB 52 over PL 426 was 15.52%. Pal *et al.,* (2018) observed significant difference in number of effective tillers in varieties may be due to genetic variability. The higher number of tillers recorded significantly in 112.5 kg seed rate ha^{-1} (81.83) over 75 kg seed rate ha^{-1} (70.20) but at par with 100 kg seed rate ha^{-1} (80.95) and 87.5 kg seed rate ha^{-1} (78.67). This is due to more plants emerged as the seeding rate was increased which is reflected on the total number of tillers per unit area. Ramadhan (2013) [13] observed that that tillers per meter square significantly increased from 339.989 to 422.448 tiller per meter square as seeding rate increased from 100 to 140 kg ha^{-1}. The interaction between varieties and seed rate for number of tillers per meter row length were non-significant.

Yield and Yield Attributes

Number of spikes per meter row length: Varieties and seed rate significantly influenced the number of spikes per meter row length. The significantly higher number of spike was observed in DWRUB 52 (118.69) over PL 426 (97.43) (Table 1). The increase in number of spike per meter row length of barley variety DWRUB 52 over PL 426 was 21.82%. Al-Myali *et al.,* (2020) [1] reported number of spikes varies with use of different barley varieties which is due to genetic variability. The significantly higher number of spikes recorded in 112.5 kg seed rate ha^{-1} (113.27) over 75 kg seed rate ha^{-1} (98.77) but at par with 100 kg seed rate ha^{-1} (112.63) and 87.5 kg seed rate ha^{-1} (107.58). Such increment in number of spikes per meter due to increasing planting density could be attributed to increasing number of plants per meter. The Haasan *et al.,* (2021) [7] also reported the same result. The interaction between varieties and seed rates for number of spikes per meter row length were found to be non-significant.

Spike length: The Spike length of barley was influenced significantly by varieties and seed rates. The variety DWRUB 52 recorded significantly higher spike length (7.32 cm) over PL 426 (6.89 cm) (Table 1). The increase in spike length of barley variety DWRUB 52 over PL 426 was 6.2%. Al-Myali *et al.,* (2020) [1] reported difference in genetic potential regarding to spike length. The higher spike length produced significantly in 100 kg seed rate ha^{-1} (7.72 cm) over 75 kg seed rate ha^{-1} (6.38 cm) and 87.5 kg seed rate ha^{-1} (6.68 cm) but was at par with 112.5 kg seed rate ha^{-1} (7.63 cm). This could be due to the availability of more nutrients for proper development of vegetative parts of plant including spike under higher doses of seed rate kg ha^{-1}. These results are in full agreement with those observed by Iqbal *et al.,* 2012 [9]. The interaction between varieties and seed rates was found non-significant.

Test weight (g): Weight of 1000-grains (g) indicates the nature and extent of seed development. Test weight of barley was influenced significantly by varieties and seed rates. The higher test weight was observed in DWRUB variety (42.13 g) over PL 426 (34.55 g). The magnitude of increase in test weight of variety DWRUB 52 over PL 426 was 21.9% (Table 1). This might be due to genetic makeup of these varieties which might lead to an increased photosynthesis and accumulations of carbohydrate in kernel to produce heavy

kernels and consequently increased kernels weight per spike. Al-Myali *et al.,* (2020) [1] also reported that the 1000-grain weight significantly affected by cultivars due to genetic variabilty. The higher test weight was significantly recorded significantly in 75 kg seed rate ha^{-1} (42.08 g) over 112.5 kg seed rate ha^{-1} (37.72 g) but was at par with 87.5 kg seed rate ha^{-1} (40.62 g) and 100 kg seed rate ha^{-1} (38.94 g). This is due to high density and high number of spikes which increases competition that reduced photosynthesis availability to grain filling and finally thousand grain weight would reduce with increasing seeding rate. Bekele *et al.,* (2020) [5] observed that when seeding rate increased from 100–175 kg ha^{-1} resulted in decreased thousand kernels weight by 23.51%. The interaction between varieties and seed rates for test weight are found to be non-significant.

Number of grains per spike: Number of grains per spike of barley was influenced significantly by varieties and seed rates. The higher number of grains per spike was observed in PL 426 variety (42.72) over DWRUB 52 (21.97) (table 2). The magnitude change in number of grains per spike of variety PL 426 over DWRUB 52 was 94.4%. Pal *et al.,* (2018) [12] reported that number of grains per spike varies with different genotype due to genetic Variabilty. The higher number of grains per spike recorded significantly in 75 kg seed rate ha^{-1} (34.57) over 112.5 kg seed rate ha^{-1} (29.97) but was par with 87.5 kg ha^{-1}(32.57) and 100 kg ha^{-1}(32.26). Bekele *et al.,* (2020) [5] reported that increasing seeding rate from 100–175 kg ha^{-1}, the number of kernels per spike was decreased by 28.2%. The interaction between varieties and seed rates are found to be non-significant.

Grain weight per spike: Grain weight per spike of barley significantly influenced the varieties and seed rates. The higher number of grain weight per spike was observed in PL 426 variety (1.49) over DWRUB 52 (0.99) (table 2). The increase in number of grain weight per spike of variety PL 426 over DWRUB 52 was 50.5%. Noshadifard and Zare (2012) [11] reported that grain weight spike^{-1} varies in different barley varieties may be due to genetic makeup of these varieties which are responsible for increasing grain weight per spike. The higher grains weight per spike recorded significantly in 75 kg seed rate ha^{-1} (1.42) over 112.5 kg seed rate ha^{-1} (1.08) and 100 kg seed rate ha^{-1} (1.20) but at par with 87.5 kg seed rate ha^{-1} (1.27). Sowing with the lowest seeding rate, resulted maximizing light interception, penetration, distribution in crop canopy and average light utilization efficiency of the leaves in the canopy, and thus affect grain weight per spike. Haasan *et al.,* (2021) [7] reported that lowest seed rate produced highest grain weight per spike (0.765g) as compared to highest seed rate (0.706 g). The interaction between varieties and seed rates for grain weight per spike are found to be non-significant.

Grain yield (q ha^{-1}): Grain yield of barley was also influenced significantly with the varieties and seed rates. The variety DWRUB 52 significantly recorded higher grain yield (39.64 q ha^{-1}) over PL 426 variety (31.97 q ha^{-1}) (table 2). The magnitude of increase in grain yield of barley variety with DWRUB 52 over PL 426 was 24.92%. This might be due to the production of higher thousand-kernel weight, number of tillers, number of spike, spike length than the other varieties. Neelam *et al.,* (2022) [10] also reported same result. The 112.5 kg seed rate ha^{-1} recorded significantly higher grain yield (40.47 q ha^{-1}) over 75 kg seed rate ha^{-1} (28.67 q ha^{-1}) and 87.5 kg seed rate ha^{-1} (34.87 q ha^{-1}) but at par with 100 kg seed rate ha^{-1} (39.22 q ha^{-1}). Increasing the seeding rate led to increase the number of plants per unit area, consequently increasing the number of tiller and this in turn caused an increase in the number of spikes thus increase grain yield. Ramadhan (2013) [13] observed that seed yield increased by 31.196% when seeding rate increased from 100 to 140 kg ha^{-1}. Grain yield interaction in varieties and seeding rate also found to be non-significant.

Straw yield (q ha^{-1}): The varieties and seed rates significantly affect the straw yield of barley. The variety DWRUB 52 recorded significantly higher straw yield (68.88 q ha^{-1}) over PL 426 variety (60.42 q ha^{-1}) (table 2). The increase in straw yield of barley variety with DWRUB 52 over PL 426 was 14%. Pal *et al.,* (2018) [12] also found that straw yield is significantly influenced by varieties due to genetic variabilty. The higher straw yield recorded significantly in 100 kg seed rate ha^{-1} (67.63 q ha^{-1}) over 75 kg seed rate ha^{-1} (58.83 q ha^{-1}) but at par with 112.5 kg seed rate ha^{-1} (67.43 q ha^{-1}) and 87.5 kg seed rate ha^{-1} (64.70 q ha^{-1}). El-Lattief (2014) [6] also concluded that maximum straw yield was observed in 300 seeds m^{-2} (6.582 t ha^{-1} in 1st year and 6.654 t ha^{-1} in 2nd year) over the 100, 200,400 seeds m^{-2}. However, the seeding 100 seeds m^{-2} treatment resulted in significant straw yields reduction of 13.6% in 1st year and 9.0% in 2nd year, respectively as compared with the 300 seeds m^{-2} treatment. The interaction between varieties and seed rate for straw yield was found to be non-significant for straw yield.

Biological yield: Biological yield is a function of the interplay of various yield components such as the number of tillers, number of spike and 1000 grain weight. Biological yield of barley was influenced significantly with the varieties and seed rates. The variety DWRUB 52 recorded significantly higher biological yield (108.52 q ha^{-1}) over PL 426 variety (92.39 q ha^{-1}). The magnitude of increase in biological yield of barley variety with DWRUB 52 over PL 426 was 17.46% (table 2). Neelam *et al.,* (2022) [10] reported that the maximum yield with the variety RD 2552 might be due to maximum number of effective tillers m^{-2} and low canopy temperature, which kept the canopy cooler that could have helped to avoid the heat stress during grain filling period. The 112.5 kg seed rate ha^{-1} recorded significantly higher biological yield (107.90 q ha^{-1}) over 75 kg seed rate ha^{-1} (87.50 q ha^{-1}) and 87.5 kg seed rate ha^{-1} (99.57 q ha^{-1}) but was at par with 100 kg seed rate ha^{-1} (106.85 q ha^{-1}). Hajighasemi *et al.,* (2016) [8] showed that biological yield increased with increasing seed rate from 400-800 seeds m^{-2}. The interaction between varieties and seed rate was found to be non-significant for biological yield.

Harvest index (%): The physiological ability of a crop plant to convert proportion of dry matter into economic yield is measured in terms of harvest index. Harvest index of barley was significantly influenced with the varieties and seed rates. The significantly higher harvest index was observed in DWRUB 52 variety (36.53) over PL 426 (34.60). The magnitude of increase in harvest index of barley with the variety DWRUB 52 over PL 426 was 5.58% (table 2). Sravani *et al.,* (2018) [16] also reported that the variation in harvest

index due to varietal differences. The higher harvest index recorded significantly in 112.5 kg seed rate ha^{-1} (37.51) over 75 kg seed rate ha^{-1} (32.76) but at par with 100 kg seed rate ha^{-1} (36.71) and 87.5 kg seed rate ha^{-1} (35.02). This could be due to that grain yield is proportional to harvest index and factors which make up grain yields such as grain weight and grains per spikes have a relatively high effect on harvest index. El-Lattief (2014) [6] concluded that from 100-400 seeds m^{-2}, the seeding 300 and 400 seeds m^{-2} produced the maximum harvest index in both seasons without significant difference between them. The interaction between varieties and seed rate was found to be non-significant for harvest index.

Table 1: Effect of varieties and seed rates on plant height, number of tillers per meter row, number of spikes per meter row length, spike length and test weight

Treatments	Plant height (cm)	Number of tillers per meter row length	Number of spikes per meter row length	Spike length (cm)	Test weight (g)
(A)Varieties					
PL 426	86.68	72.30	97.43	6.89	34.55
DWRUB 52	93.91	83.53	118.69	7.32	42.13
C.D at 5%	4.87	4.89	7.08	0.39	2.25
SE(m)	1.59	1.59	2.31	0.13	0.74
(B)Seed rate kg per hectare					
75.0	84.89	70.20	98.77	6.38	42.08
87.5	89.46	78.67	107.58	6.68	40.62
100.0	94.34	80.95	112.63	7.72	38.94
112.5	92.50	81.83	113.27	7.63	37.72
CD at 5%	6.89	6.91	10.01	0.55	3.19
SE(m)	2.25	2.26	3.27	0.18	1.04
Interaction	NS	NS	NS	NS	NS
SE(m)	3.18	3.19	4.62	0.25	1.47
CV(%)	6.10	7.10	7.40	6.13	6.40

Table 2: Effect of varieties and seed rates on number of grains/spike, grain weight/spike (g), grain yield, Straw yield, Biological yield and harvest index (%).

Treatments	Number of grains/spike	Grains weight (g)/spike	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
(A)Varieties						
PL 426	42.72	1.49	31.97	60.42	92.39	34.60
DWRUB 52	21.97	0.99	39.64	68.88	108.52	36.53
C.D at 5%	1.85	0.11	2.72	4.36	5.76	1.92
SE(m)	0.60	0.04	0.89	1.42	1.88	0.63
(B)Seed rate kg per hectare						
75.0	34.57	1.42	28.67	58.83	87.50	32.76
87.5	32.57	1.27	34.87	64.70	99.57	35.02
100.0	32.26	1.20	39.22	67.63	106.85	36.71
112.5	29.97	1.08	40.47	67.43	107.90	37.51
CD at 5%	2.61	0.16	3.84	6.17	8.15	2.72
SE(m)	0.85	0.05	1.25	2.01	2.66	0.89
Interaction	NS	NS	NS	NS	NS	NS
SE(m)	1.20	0.07	1.77	2.85	3.76	1.26
CV(%)	6.46	10.20	8.58	7.63	6.49	6.13

Conclusion

Based on the present study, it can be concluded that barley variety DWRUB 52 may be preferred because of its significantly higher grain yield, straw yield, biological yield and harvest index compared to PL 426. The 112.5 kg seed rate ha^{-1} recorded significantly higher grain yield over 75 kg seed rate ha^{-1} and 87.5 kg seed rate ha^{-1}, however, it showed statistically non-significant with 100 kg seed rate ha^{-1}, which exhibits the better preference of 100 kg ha^{-1} compared to other.

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