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PER SE PERFORMANCE AND SELECTION STRATEGIES IN BARLEY UNDER ORGANIC FIELD CONDITION

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SUMMARY

In order to elucidate the *per se* performance and selection strategies for development of high yielding varieties and/ or promising genotypes under organic condition, 12 varieties of barley were grown and evaluated for 10 metric traits during *rabi* 2015-16 at Experimental Area of Wheat and Barley Section of Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar. The analysis of variance indicated high significance of mean sum of squares due to treatments for all the traits studied. Three varieties *viz*., BH 946, BH 902 and DWRB 101 produced higher grain yield and also showed better performance for several other yield components. These genotypes can be used in barley improvement programme and will be helpful in breaking the yield plateau under organic field condition. Moderate to high heritability coupled with high genetic advance was revealed by grains per spike, grain yield per plot, peduncle length, spike length and plant height. Correlation analysis indicated highest significant positive correlation of grain yield per plot with biological yield per plot, followed by harvest index and days to maturity at both genotypic and phenotypic levels. Among all the traits, biological yield per plot, harvest index, spike length and peduncle length reflected positive direct effect on grain yield per plot. Therefore, to obtain high yield, one should consider these traits in barley breeding programme.

Key words : Barley, *per se* performance, genetic variability, organic condition

Barley, a nutri-rich cereal, nationally occupied an area of 0.62 million hectare with production of 1.59 million tonnes during the crop season 2019-20 (ICAR-IIWBR 2020). It was cultivated on 12,200 hectares with a production level of 44,000 tons in Haryana which ranks second in average productivity (3607 kg/ha) after Punjab (3767 kg/ha).

The role of both organic and conventional farming remains open to debate particularly when related to food security and climate change. Targeting plant breeding to organic farming can contribute to reduce its yield gaps vis-a-vis conventional farming (Crespo-Herrera and Ortiz, 2015). Yields in organic agriculture tend to fluctuate than in conventional systems and there is a need for varieties with higher and more stable yields (Wolfe *et al*., 2008). Regular testing of varieties in organic conditions would give valuable information to find the genotypes that are better adapted to specific conditions and help farmers to choose appropriate varieties (Bleidere *et al*., 2019). However, barley varieties used in conventional agriculture are not always the higher yielding varieties in organic systems (Murphy *et al*. 2007). Till now, interest in breeding for organic agriculture has been limited to a handful of small-scale breeders. However, rising input prices, the increasing impact of climate change and the need for sustainability are creating a larger opportunity for the specific breeding objectives needed (Wolfe *et al*., 2008).

To date, there are only a few varieties specifically bred for organic and low-input systems in developed countries. It is estimated that more than 95% of organic agriculture is based on crop varieties bred for the conventional high-input sector with selection in conventional breeding programmes. Various studies have shown that such varieties lack important traits required under organic and low-input production conditions (Bueren *et al*., 2011). A range of breeding goals desired for the organic sector, such as yield, resistance to biotic and abiotic stress and sensory qualities demanded by consumers do not differ from conventional breeding goals, but it is essential that such traits are expressed under low-input conditions, which cannot be guaranteed if selection is done in high-input agronomic backgrounds.

To realize the varietal improvements needed in organic farming in the coming decades, crosses between appropriate parental varieties have to be made now. It is essential, therefore, to identify the existing varieties for organic production and target them in the breeding programmes for organic farming and subsequently communicate results to public and commercial breeders. This study describes the performance of barley varieties and selection strategies required for yield enhancement under organic field conditions.

MATERIALS AND METHODS

Plant material and experimental design : The experimental material consisted of 12 varieties of barley representing both 2-row (4) and 6-row (8) types, evaluated under organic field condition. The field experiment was carried out during *Rabi* 2015-16 at Research Area of Wheat and Barley Section, Department of Genetics and Plant breeding, CCS, Haryana Agricultural University, Hisar. Geographically, Hisar is situated in the semi-arid subtropics at 29°10' N latitude and 75°46' E longitude with an altitude of 215.2 meters above the mean sea level.

The experiment was planted on 26th November, 2015 in Random Block Design with three replications. Each variety was sown in six rows of 5 m length with row-to-row spacing of 23 cm. The recommended cultural and agronomic practices were followed to raise crop. Since the study is carried out under organic field condition, so no chemical synthetic inputs, such as chemical fertilizers, herbicides and pesticides were applied. Only FYM @ 10 tons per hectare was applied. Weather parameters were also recorded during crop season. The weather parameters during the crop season *i.e.* 1st November 2015 to 30th April 2016 were also recorded (*Fig.* 1). Monthly mean maximum temperature varied between 19.6 to 37.9 °C whereas, the monthly mean minimum temperature was between 6.0 to 18.4 °C. Morning RH varied from 60.7 to 95.8% while evening RH was highly variable with a range of 25.4 to 64.5%. Total amount of rainfall received during the season at Hisar was 33.4 mm.

Observation procedure : Observations were recorded on 10 metric traits namely, days to heading, days to maturity, tillers per plant, spike length (cm), plant height (cm), peduncle length (cm), grains per spike, biological yield (q/ha), grain yield (q/ha) and harvest index (%). Five randomly selected competitive plants in each replication were recorded for all the traits under study excepting days to heading and maturity, biological yield and grain yield which were recorded on plot basis. Further, the value of harvest

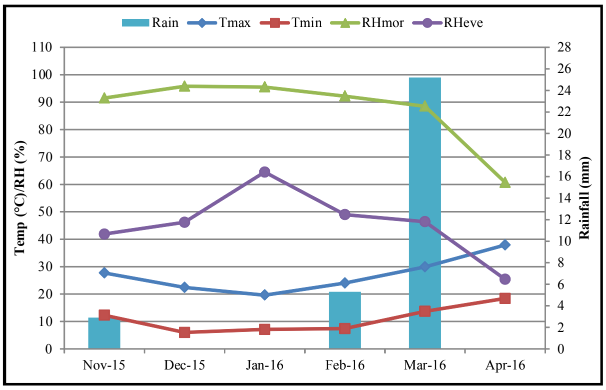

Fig. 1. Weather parameters during crop season.

index was calculated as per the formula given by Donald and Humblin (1976).

Statistical analysis : Analysis of variance to test the significance for each character was carried out as per methodology advocated by Fisher (1925) and described by Panse and Sukhatme (1967). Phenotypic coefficient of variability (PCV) and Genotypic coefficient of variability (GCV) were calculated by the formula given by Burton (1952), heritability in broad sense (h^2) was calculated by using the formula suggested by Hanson *et al.* (1956) and genetic advance that is the expected genetic gain was calculated by using the procedure given by Johnson *et al.* (1955). Correlation and path coefficients were worked out as per method suggested by Al-Jibouri *et al.* (1958) and Dewey and Lu (1959), respectively.

RESULTS AND DISCUSSION

Per se performance : The analysis of variance indicated high significance of mean sum of squares due to treatments for all the traits studied (Table 1), which justified further genetic analysis of the data for the objectives of experiment. The genetic variability explored in the experimental material, can be utilized for genetic improvement of barley. Mean performance and estimates of genetic variability for 10 traits were calculated for 12 barley varieties and depicted in Table 2. The minimum number of days for heading was noted for BH 393 (75.5) and C 138 (80.3); however, late heading was exhibited also by two varieties *i.e.* BH 902 (101.0) and RD 2552 (100.5). The general mean for this character was 90.4 while, it was 134.6 for days to maturity. The earliest maturing genotype among all was BH 393 (127.5). This character varied from 127.5 to 139.8 days and results indicates that BH 393 matured significantly earlier than the general mean. The general mean for plant height was 82.4 cm. Three varieties *viz.*, DWRB 101 (67.8 cm),

TABLE 1
Mean sum of squares for different traits

Source of Variation		Mean sum of squares									
	d. f.	DH	DM	T/P	SL	PH	PL	G/S	BY	GY	HI
Replication	3	52.187	24.24	2.67	0.36	414.00	10.49	94.31	166.57	20.40	3.75
Treatment	11	299.84**	42.98**	4.12**	4.83**	384.35**	9.20**	1565.36**	354.55**	90.47**	39.63**
Error	33	7.58	5.88	1.11	0.36	32.01	0.91	15.88	47.26	3.37	5.15

**Significant at 1 % level of significance; (DH: Days to heading, DM: Days to maturity, T/L: Tillers per plant, SL: Spike length, PH: Plant height, PL: Peduncle length, G/S: Grains per spike, BY: Biological yield per plot, GY: Grain yield per plot, HI: Harvest index).

DWRUB 52 (73.3 cm) and BH 393 (73.7 cm) were significantly shorter in plant stature than the general mean. Przystalski *et al.*, 2008 also compared the performance of cereal varieties in organic and non-organic cropping systems. For lodging resistance, these genotypes could be incorporated in breeding barley. Spike length ranged from 6.7 to 10.5 cm with a general mean of 8.2 cm. BG 25 recorded with longest spike while, DWRB 101 and DWRUB 52 exhibited shortest spike length. Among all, only BG 25 (10.5cm) showed significantly longer spike than general mean. The number of tillers per plant was found maximum in DWRB 101 (10.9) followed by BH 393 (9.8) whereas; C 138 had the minimum number of tillers (7.2) per plant. One variety (DWRB 101) had significantly higher tillers than the general mean of 8.8 for this trait. Number of grains per spike ranged from 23 to 69 with general mean of 50.5 and was recorded highest in BG 25 (69). The lowest and highest values for peduncle length were recorded for DWRB 92 (7.1 cm) and BG 25 (11.6 cm), respectively. The general mean for biological yield was 71.9 q/ha and varied from 58.8 q/ha (BH 885) to 89.5 q/ha (BH 946). Three varieties *viz*., BH 946, BH 902 and DWRB 101 identified significantly superior for biological yield. Harvest index as expressed in per cent ranged from 32.5 to 41.3 % and only one variety *i.e.* DWRB 92 was found significantly better for this character. Borgen *et al.* (2010) also studied agronomic and quality traits of Danish heritage spring wheat and barley varieties under organic cropping conditions and compared them with modern varieties. The general mean calculated for grain yield was 27.2 q/ha that ranged from 22.1 q/ha to 36.3 q/ha. Among all, three varieties namely BH 946 (36.3 q/ha), BH 902 (33.9 q/ha) and DWRB 101(32.8 q/ha) were found significantly promising for grain yield over the general mean and also showed better performance for several other yield components. These genotypes can be used in barley improvement programme and will be helpful in breaking the yield plateau under organic field condition. Different barley varieties were also compared for yield and yield stability to select the genotypes effectively for conventional and organically management conditions by some researchers (Bleidere *et al.*, 2019 and Kokare *et al.*, 2014).

The wide range of variation as observed among the characters studied would be helpful in the selection of superior and desired genotypes for further improvement and exploitation through selection, hybridization and combination breeding. The wide and exploitable variations for these characters in different barley genotypes were also observed earlier by Devi, 2016.

The genetic relationship among all the 12 barley varieties based on Euclidean distance was presented in the dendrogram (Fig. 2). Similar relationship was also reported in barley by Kumar *et al.* (2020).

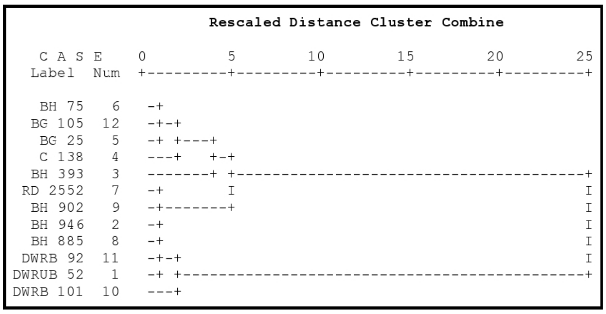

Fig. 2. Dendogram represents genetic relationship among barley varieties based on Euclidean distance.

Genetic variability, heritability and genetic advance : The magnitude of phenotypic coefficient of variation in the present investigation was slightly higher than genotypic coefficient of variation for all the characters (Table 2), which revealed the less sensibility of characters to environmental factors under organic condition. The high estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed for grains

TABLE 2
Mean performance and variability estimates for different traits

Varieties	DH	DM	T/P	SL	PH	PL	G/S	BY	GY	HI
DWRUB 52	82.0*	135.5	9.5	6.7	73.3*	9.5	23.0	67.5	26.1	38.7
BH 946	88.3	138.0	8.4	8.4	84.1	8.1	65.0	89.5*	36.3*	40.7
BH 393	75.5*	127.5*	9.8	7.9	73.7*	7.2	63.5	61.4	24.7	40.4
C 138	80.3*	131.8	7.2	8.3	92.6	11.1*	59.5	66.0	22.3	33.8
BG 25	92.8	132.8	9.3	10.5*	98.9	11.6*	69.0	66.9	22.1	33.1
BH 75	97.3	133.5	7.9	8.3	93.3	10.4	64.0	70.8	25.7	36.5
RD 2552	100.5	138.5	8.8	7.2	81.4	8.9	63.0	73.0	27.3	37.8
BH 885	90.5	133.8	8.5	9.0	75.4	10.4	25.0	58.8	23.0	39.1
BH 902	101.0	139.8	8.3	8.2	79.2	8.7	65.5	85.4*	33.9*	39.8
DWRB 101	82.5*	134.5	10.9*	6.7	67.8*	8.7	24.5	81.8*	32.8*	40.3
DWRB 92	94.5	135.0	9.4	7.6	77.1	7.1	23.0	67.6	27.9	41.3*
BG 105	99.3	134.8	7.9	9.3*	92.4	10.9*	60.5	73.8	23.9	32.5
GM	90.4	134.6	8.8	8.2	82.4	9.4	50.5	71.9	27.2	37.8
S.E. (d)	1.95	1.72	0.74	0.43	4.00	0.67	2.82	4.86	1.30	1.61
CD (0.05)	3.98	3.50	1.52	0.87	8.25	1.38	5.76	9.93	2.65	3.28
GCV (%)	9.46	2.26	9.84	12.92	11.39	15.37	39.01	12.20	17.18	7.76
PCV (%)	9.94	2.89	15.46	14.87	13.30	18.43	39.80	15.50	18.46	9.81
Heritability (%)	90.60	61.20	40.49	75.50	73.35	69.51	96.06	61.91	86.61	62.58
Genetic Advance (% of mean)	18.55	3.65	12.90	23.12	20.09	26.39	78.75	19.77	32.93	12.65

*Significantly superior over the general mean.

per spike, followed by grain yield per plot and peduncle length whereas, moderate to low estimates of GCV and PCV were observed for traits like spike length, biological yield per plot, plant height, tillers per plant, days to heading and harvest index. Days to maturity exhibited least genotypic and phenotypic coefficients of variation. Above findings were supported by earlier observations (Kumar *et al*., 2013).

Genotypic coefficient of variation along with heritability and genetic advance was identified as good estimates of genetic gain to be expected from selection on phenotypic basis. The estimates of heritability (broad sense) varied from 40.49 to 96.06 per cent and was recorded highest for grains per spike followed by days to heading, grain yield per plot and spike length. However, tillers per plant showed low heritability among all traits. Kokare *et al*., 2014 also reported low heritability of yield components under organic condition as compared with conventional conditions. Heritability for yield components was lower than those for yield itself. Selection for yield components, therefore, may be less effective than selection directly employed for grain yield.

Further, the genetic advance as *per cent* of mean observed high for characters like grains per spike, followed by grain yield per plot, peduncle length and spike length, while the estimates were moderate for plant height, biological yield per plot and days to heading.

Simple selection could be effective for the improvement of the traits possessing high heritability coupled with high genetic advance. Moderate to high heritability coupled with high genetic advance for traits *viz*., grains per spike, grain yield per plot, peduncle length, spike length and plant height indicated additive gene effects. These results are also in close agreement with the findings of Kumar *et al*., 2018. Hence, simple selection can be effective for further improvement of these traits. The selection under conventional conditions (indirect selection) is as effective as selection under organic conditions (direct selection) to develop varieties suitable for organic farming systems (Kokare *et al.,* 2017).

High genetic variations combined with high heritability could provide effective selection of phenotypic trait for further improvement in barley through hybridization. Johnson *et al*. (1955) also stated that heritability estimates coupled with genetic advance were more helpful than heritability alone in predicting the progress from the selected better genotypes. Furthermore, the use of broad sense heritability has limitations as it includes both additive and non-additive gene effects. Therefore, it is necessary to estimate broad sense heritability in conjunction with the genetic advance.

Correlation coefficient : The result of correlation analysis indicated that the absolute values of genotypic correlation coefficient were slightly higher than corresponding phenotypic correlation coefficient for most of the interrelationships among 10 studied traits (Table 3).

In the present study, the grain yield per plot exhibited highest positive significant correlation at both genotypic and phenotypic levels with biological yield per plot (0.917, 0.851), followed by harvest index (0.721, 0.493) and days to maturity (0.702, 0.534). If selection is made for any of these traits, simultaneous selection of the all the traits could be achieved. The concurrent results were also reported by Kumar *et al.* (2018) for spike length, plant height, biological yield and harvest index. Further, significant negative correlation was recorded for grain yield per plot with spike length (-0.445, -0.377), plant height (-0.451, -0.339) and peduncle length (-0.646, -0.460) both at genotypic and phenotypic levels. Legzdina *et al.* (2010) also studied the correlation in barley among grain yield and other traits under organic condition. Hence, the characters *viz.*, biological yield per plot, harvest index and days to maturity could be considered as criteria for selection for higher grain yield as these were directly associated with grain yield. Longer days to maturity sometimes lead to heat stress. So linkage of this trait may be considered while breeding for such a genotype.

Significant positive association was also observed for days to heading with days to maturity and plant height; days to maturity with biological yield per plot; spike length with plant height, peduncle length and grains per spike; plant height with peduncle length and grains per spike; and harvest index with tillers per plant at genotypic as well as phenotypic level. Similarly, significant negative correlation was found for tillers per plant and harvest index with spike length, plant height, peduncle length and grains per spike at both genotypic and phenotypic levels. These negative associations are to be turned up otherwise for crop improvement.

Path analysis : Correlation coefficients reveal the extent and nature of association between yield and its attributes but does not exhibit the direct and indirect effects of different contributing traits towards yield *per se* performance. When more variables are considered simultaneously in correlation, their indirect associations become more complicated, less obvious and somewhat perplexing. Consequently, path coefficient analysis provides an effective means of splitting direct and indirect cause of association and also provides an opportunity of critical evaluation of that specific cause acting to produce a given correlation and also measures the relative importance of each causal factor.

The estimates of path coefficients were calculated and are presented in Table 4. The estimates of residual effect (0.001) reflect the adequacy and appropriateness of the characters chosen for path analysis. Among all the traits under study, biological yield per plot, harvest index, spike length and peduncle length reflected positive direct effect on grain yield per plot (0.788, 0.454, 0.027 and 0.020, respectively). Spike length and peduncle length though have negative association with grain yield per plot but they contributed towards grain yield directly as well indirectly *via* tiller per plant. This signifies that direct selection based on these traits would result in higher breeding efficiency for improving grain yield. Accordingly, these traits might be considered as the

TABLE 3

Genotypic (above diagonal) and phenotypic correlation coefficients (below diagonal) among different traits

Traits	GY	DH	DM	T/P	SL	PH	PL	G/S	BY	HI
GY	**1.000**	0.128	0.702**	0.269	-0.445**	-0.451**	-0.646**	-0.016	0.917**	0.721**
DH	0.118	**1.000**	0.722**	-0.460**	0.322**	0.394**	0.199	0.278	0.312	-0.208
DM	0.534**	0.525**	**1.000**	-0.194	-0.244	-0.091	-0.099	-0.006	0.788**	0.267
T/P	0.212	-0.273	-0.124	**1.000**	-0.526**	-0.907**	-0.620**	-0.609**	-0.028	0.680**
SL	-0.377**	0.263	-0.083	-0.296*	**1.000**	0.803**	0.673**	0.513**	-0.189	-0.721**
PH	-0.339*	0.327*	-0.037	-0.320*	0.649**	**1.000**	0.719**	0.713**	-0.061	-0.948**
PL	-0.460**	0.133	-0.115	-0.314*	0.481**	0.640**	**1.000**	0.226	-0.291*	-0.909**
G/S	-0.017	0.260	0.005	-0.355*	0.461**	0.596**	0.180	**1.000**	0.267	-0.487**
BY	0.851**	0.278	0.556**	0.055	-0.158	-0.024	-0.166	0.209	**1.000**	0.386**
HI	0.493**	-0.215	0.102	0.310*	-0.475**	-0.611**	-0.613**	-0.388**	-0.034	**1.000**

*, **Significant at 5 % and 1% level of significance, respectively; (DH: Days to heading, DM: Days to maturity, T/L: Tillers per plant, SL: Spike length, PH: Plant height, PL: Peduncle length, G/S: Grains per spike, BY: Biological yield per plot, GY: Grain yield per plot, HI: Harvest index).

TABLE 4
Direct (diagonal values) and indirect effects of different components traits on grain yield

Traits	DH	DM	T/P	SL	PH	PL	G/S	BY	HI	Correlation with GY
DH	**-0.015**	-0.023	0.021	0.009	-0.010	0.004	-0.008	0.246	-0.095	0.128
DM	-0.011	**-0.032**	0.009	-0.007	0.002	-0.002	0.000	0.621	0.121	0.702**
T/P	0.007	0.006	**-0.046**	-0.014	0.024	-0.012	0.018	-0.022	0.309	0.269
SL	-0.005	0.008	0.024	**0.027**	-0.021	0.013	-0.015	-0.149	-0.327	-0.445**
PH	-0.006	0.003	0.041	0.022	**-0.026**	0.014	-0.021	-0.048	-0.430	-0.451**
PL	-0.003	0.003	0.028	0.018	-0.019	**0.020**	-0.007	-0.229	-0.458	-0.646**
G/S	-0.004	0.000	0.028	0.014	-0.019	0.005	**-0.029**	0.211	-0.221	-0.016
BY	-0.005	-0.026	0.001	-0.005	0.002	-0.006	-0.008	**0.788**	0.175	0.917**
HI	0.003	-0.009	-0.031	-0.020	0.025	-0.020	0.014	0.304	**0.454**	0.721**

Residual factor = 0.001; (DH: Days to heading, DM: Days to maturity, T/L: Tillers per plant, SL: Spike length, PH: Plant height, PL: Peduncle length, G/S: Grains per spike, BY: Biological yield per plot, GY: Grain yield per plot, HI: Harvest index).

most important component traits for grain yield in barley under organic condition. Days to heading and tillers per plant exhibited non significant positive correlation with grain yield, however these traits have negative direct effect but they contributed to grain yield indirectly through biological yield and harvest index, respectively. Grains per spike showed negative direct effect as well as negative correlation with grain yield, even though contributed to yield *via* biological yield per plot. Days to maturity although revealed positive significant relationship with grain yield, also recognized its contribution indirectly *via* biological yield per plot, even had negative direct effect. These results corroborate with earlier findings of Kumar *et al*., 2013 and Kumar *et al*., 2018.Thus improvement can be made through improvement or selection in traits not directly involved in yield enhancement.

CONCLUSION

The present investigation revealed existence of wide variation, coupled with moderate to high heritability and genetic advance as *per cent* of mean, for different characters of barley under organic field condition. It offers potential to evolve high yielding barley varieties through simple breeding methods. The improvement for grain yield in barley could be achieved on the basis of selection of various characters like biological yield per plot, harvest index which were positively correlated with grain yield. In addition, perusal of path analysis revealed positive direct and high indirect effects of biological yield per plot, harvest index, days to maturity and tillers per plant on grain yield. Therefore, to obtain high yield, one should consider these traits in barley breeding programme. Improvement can be made by following the strategies of yield enhancement through betterment of all contributing traits directly or indirectly.

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