J. Agric. Res. Technol., 49 (3) : 508-516 (2024)

Elucidation of Barley Genotypes for Selection Approaches based on Morpho-Physiological Traits

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(Received : 12.07.2024 Accepted : 14.08.2024)

Abstract

The present study designed to identify component traits for development of high yielding barley varieties through estimation of various morpho-physiological characters. The experiment was conducted at Research Area of the Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during 2021-22 with fourty four genotypes of barley under timely sown and heat stress conditions. In general, the results showed wide range for all the traits under investigation. The results of phenotypic and genotypic coefficient of variation under both environments revealed high estimates for number of grains per spike; moderate estimates for peduncle length, biological yield per plant and canopy temperature depression at anthesis. However, days to heading and maturity, plant height, SPAD chlorophyll content at anthesis and normalized difference vegetation index at anthesis exhibited low estimates of phenotypic and genotypic coefficient of variation under normal as well as under heat stress conditions. High heritability coupled with genetic advance was observed for number of grains per spike, 1000-grain weight, biological yield plant^{-1} and grain yield plant^{-1} under normal sown similarly, under heat stress the traits *viz*., peduncle length, number of grains spike^{-1}, biological yield plant^{-1} and canopy temperature depression at anthesis and at 15 day after anthesis exhibited high heritability with high genetic advance, indicates the importance of these traits in selection and crop improvement. Consequently, it is suggested that the parameters with high heritability coupled with high genetic advance can be considered as key component traits while setting the selection criterion for barley improvement for timely sown and heat stress conditions.

Key words : Barley, GCV, PCV, heritability, genetic advance, heat stress.

Barley (*Hordeum vulgare* L.) is one of the ancient domesticated cereal crops, belongs to the genus Hordeum in the tribe Triticeae of the grass family, Poaceae (also known as Gramineae). In world cereal production, it ranks fourth after rice, wheat and maize (Swati *et al*., 2019). In India, barley occupied an area and production of 0.62 million hectare and 1.69 million tonnes grain, respectively with productivity of 27.33 q ha^{-1}. Barley was cultivated on 15,300 hectares with a production of 53,300 tons in Haryana state that ranked second in average productivity (34.86 q ha^{-1}) after Punjab (36.54 q ha^{-1}) during 2022-23 (ICAR-IIWBR, 2023). Barley can thrive in various agro-climatic conditions that allow its cultivation on marginal and stress-prone environments. It was initially utilized for animal fodder, but now-a-day it is also used in multigrain blends, health tonics, malting as well as in brewing industries (Kaur *et al*., 2018). Barley contains low gluten content as well as possessed high fiber and beta-glucan, aiding in weight management and cholesterol reduction (Abebaw, 2021).

The extent of genetic variability in the original breeding population, as well as the degree to which desirable characters are inherited, determines the progress of any breeding programme. Hence, the hereditary studies as well as the expected genetic progress from selection are extremely valuable and should be measured, as heritability alone is not a good

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indicator of usable genetic variability. The genetic variability assessment is quite important for initiation of any crop improvement programme. Grain yield is a complex trait that is highly reliant on the interrelationships between the various yield components and is also affected by various environmental factors. In order to choose appropriate breeding approach for different environments, it is critical to understand component traits linked to grain yield, as in all of the breeding activities, increasing grain production is a major concern.

Therefore, the present study was designed and conducted with fourty four barley genotypes to assess various morpho-physiological characters aimed to identify component traits for their utilization in developing high yielding barley varieties for timely sown and heat stress conditions.

Materials and Methods

The experiment was performed at the Research Area of the Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar during the year 2021-22. The experimental material consisted of fourty four genotypes of barley that represented both 2-row (23) and 6-row (21) types including four check varieties (Table 1). The check varieties included were DWRB 123 and BH 946 that were used to compare the performance of genotypes under timely sown; and DWRB 91 and DWRUB 64 were used for heat stress (late sown) comparison. The experiment was laid in Randomized Block Design (RBD) with three replications. Each genotype was raised in paired rows of 2.5 m length spaced at 23 cm apart. The experimental material was sown on 20th November, 2021 under timely sown and on 20th December, 2021 for heat stress conditions. The late sown material was expected to face terminal heat stress during grain filling. The package of practices recommended for both environmental conditions were applied to raise the crop.

The observations were recorded for twelve morphological traits *viz*., days to heading, days to maturity, grain filling duration, number of effective tillers plant^{-1}, plant height (cm), peduncle length (cm), spike length (cm), number of grains spike^{-1}, 1000-grain weight (g), biological yield plant^{-1} (g), grain yield plant^{-1} (g), and harvest index (%). In addition, six physiological parameters namely canopy temperature depression at anthesis (CTD 1) and 15 days after anthesis (CTD 2), normalized difference vegetation index at anthesis (NDVI 1) and 15 days after anthesis (NDVI 2), and SPAD chlorophyll content at anthesis (SPAD 1) and 15 days after anthesis (SPAD 2) were also measured.

Genotypic and phenotypic coefficients of variation were calculated by the formula given by Burton (1952). Heritability in broad sense was calculated according to the formula suggested by Hanson *et al*. (1956). Estimates of appropriate variance components were substituted for the parameters to predict expected genetic gain suggested by Lush (1949) and Johanson *et al*. (1955). The genotypic and phenotypic coefficients of variation as well as genetic advance were classified as low (<10%), moderate (10-20%) and high (>20%) while, heritability was categorized as low (<40%), moderate (40-60%) and high (>60%). The recorded observations were subjected to statistical analysis using software OPSTAT available at http://14.139.232.166/opstat/default.asp (Sheoran *et al*., 1998).

Results and Discussion

The study of variability and their division into its various components present a clear picture of the genetic basis of the characters. The impact of environment on a trait can easily be measured with the use of genetic parameters like

GCV, PCV, heritability, and genetic progress. An appropriate breeding program can be employment to improve the trait depending on its genetic make-up and the degree of environmental effect on its expression. Different genetic parameters have been estimated to determine the extent and type of variability present in the experimental material, pertaining to various morphological and physiological traits and are presented in Table 2 and 3 for timely sown and heat stress conditions, respectively. The results of the present study revealed a wide range for all the traits studied under both the environments.

Genotypic coefficient of variation : The phenotypic coefficient of variation (PCV) is constituted by the linear combination of genotypic and environmental coefficient of variation. Hence, along PCV whether high or low can't be sole determinant of the presence of usable variation in the genotypes. To avoid any false positive, PCV is studied and compared with GCV to determine the actual nature of the traits under study. The genotypic coefficient of variation (GCV) was found to be lower than the corresponding phenotypic coefficient of variation (PCV) for all the characters studied under both environments, indicating the impact of environment on the expression of these traits. Under normal and heat stress conditions, GCV varied from 0.96 to 40.14% and 1.48 to 41.15%, respectively. The perusal of data (Table 2) revealed high estimates of GCV for number of grains per spike and moderate for grain yield per plant, canopy temperature depression at 15 days after anthesis, biological yield per plant, 1000-grain weight, peduncle length, and canopy temperature depression at anthesis, whereas, low GCV was found for traits like grain filling duration, SPAD chlorophyll content at anthesis, number of effective tillers per plant, spike length, SPAD chlorophyll content at 15 days after anthesis, harvest index, plant height, normalized difference vegetation index at 15 days after anthesis, days to heading, normalized difference vegetation index at anthesis and for days to maturity under normal sown environment. Similar findings were also observed in the study of Sunil *et al*. (2017) and Kumar and Sehrawat (2021) for biological yield, grain yield, days to heading and maturity, and

Table 1. Barley genotypes used in the study

Genotypes	RT	Genotypes	RT	Genotypes	RT
BH 1029	6	IBON-HI-2021-27	2	7th GSBON-2020-90	6
BH 1034	2	IBON-HI-2021-31	2	IBON-HI-2020-6	6
BH 1035	2	IBON-HI-2021-33	2	IBON-HI-2020-51	6
BH 1036	2	IBON-HI-2021-38	2	7th GSBON-2020-140	6
BH 1038	6	IBON-HI-2021-52	2	IBON-HI-2020-55	2
BH 1039	6	IBON-HI-2021-56	2	7th GSBON-2020-101	2
BH 1018	2	IBON-HI-2021-81	6	IBYT-HI-2020-6	6
BH 1025	2	IBON-HI-2021-85	6	7th GSBYT-2020-20	6
BH 1026	2	IBON-HI-2021-99	6	IBYT-HI-2020-11	6
BH 1027	2	IBON-HI-2021-102	6	IBON-HI-2020-155	6
IBYT-HI-2021-3	2	RD 3002	6	DWRB 123 (c)	2
IBYT-HI-2021-9	2	DWRB 197	2	BH 946 (c)	6
IBYT-HI-2021-15	6	DWRB 209	2	DWRB 91 (c)	2
IBYT-HI-2021-17	2	BCLA 11-6	6	DWRUB 64 (c)	6
IBYT-HI-2021-18	6	IBON-HI-2020-71	2		

RT : Row Type

harvest index; Matin *et al*. (2019), Hailu *et al*. (2016), Kumar *et al*. (2013), Shiferaw *et al*. (2020) and Devi *et al*. (2020) for number of grains per spike and plant height; Shehrawat and Kumar (2021) and Shehrawat *et al*. (2021) for peduncle length, 1000-grain weight, grain filling duration, and spike length; Kumar and Sehrawat (2021), Tahar *et al*. (2015), Almohisen *et al*. (2021) and Katiyar *et al*. (2020) for number of effective tillers; Shehrawat *et al*. (2021) for canopy temperature depression at anthesis, normalized difference vegetation index at anthesis and SPAD chlorophyll content at anthesis.

Under heat stress condition (Table 3), number of grains per spike showed high estimates of GCV followed by canopy temperature depression at 15 days after anthesis. Likewise, moderate GCV was observed for peduncle length, biological yield per plant, canopy temperature depression at anthesis and grain yield per plant, however characters namely grain filling duration, harvest index, spike length, 1000-grain weight, SPAD chlorophyll content at anthesis, number of effective tillers per plant, plant height, SPAD chlorophyll content at 15 days after anthesis, days to heading, normalized difference vegetation index at anthesis and days to maturity exhibited low estimates of genotypic coefficient of variation. These findings confirm with the results obtained by Shehrawat and Kumar (2021) for peduncle length, grain filling duration, spike length, SPAD chlorophyll content at 15 days after anthesis and normalized difference vegetation index at anthesis and normalized difference vegetation index at 15 days after anthesis; and Devi *et al*. (2020) for

Table 2. Genetic variability parameters for different traits in barley under timely sown condition

Traits	Mean	Range	PCV (%)	GCV (%)	Heritability (bs)(%)	GA (% mean)
DH	92.62	85.33 - 97.33	3.24	2.80	74.23	4.96
DM	133.61	130.67 - 136.67	1.82	0.96	27.78	1.04
GFD	31.89	27.00 - 38.67	11.07	8.32	56.49	12.89
ETP	17.63	14.67 - 20.22	10.01	7.48	55.88	11.52
PH	109.93	95.22 - 121.67	6.89	5.21	57.21	14.12
PL	13.73	9.25 - 17.47	15.64	12.20	60.84	19.61
SL	9.00	6.81 - 11.09	14.01	7.26	46.87	7.75
GPS	51.1	26.22 - 80	40.61	40.14	97.71	81.74
TGW	40.97	30.87 - 47.03	17.16	15.98	86.64	30.63
BYP	68.38	45.94 - 109.43	18.84	16.97	81.09	31.47
HI	39.50	32.59 - 45.29	10.17	5.34	27.61	5.78
GYP	27.01	18.67 - 39.60	20.78	18.51	79.39	33.98
SPAD 1	46.26	33.23 - 53.07	9.61	7.79	65.69	13.00
SPAD2	40.15	32.23 - 45.93	10.27	6.79	43.78	9.26
NDVI 1	0.80	0.77 - 0.84	2.32	1.71	54.39	2.60
NDVI 2	0.67	0.56 - 0.78	10.52	4.65	59.58	4.24
CTD1	5.22	3.80 - 6.50	15.27	10.86	50.55	15.90
CTD 2	3.20	1.72 - 4.47	25.71	17.50	46.33	24.54

DH: Days to heading, DM: Days to maturity, GFD: Grain filling duration, ETP: Number of effective tillers per plant, PH: Plant height, PL: Peduncle length, SL: Spike length, GPS: Number of grains per spike, TGW: 1000-grain weight, BYP: Biological yield per plant, HI: Harvest index, GYP: Grain yield per plant, SPAD 1: Chlorophyll content (SPAD) at anthesis, SPAD 2: Chlorophyll content (SPAD) at 15 days after anthesis, NDVI 1: Normalized difference vegetation index at anthesis, NDVI 2: Normalized difference vegetation index at 15 days after anthesis, CTD 1: Canopy temperature depression at anthesis, CTD 2: Canopy temperature depression at 15 days after anthesis

number of grains per spike, biological yield, days to heading and maturity, and plant height. Kumar *et al*. (2018) also observed variation for physiological traits in barley under stress condition.

Phenotypic coefficient of variation : The estimates of phenotypic coefficient of variation varied from 1.82% to 40.61% and 1.87 to 41.69% under normal and stressed environments, respectively. High estimates of PCV were observed under normal sown for number of grains per spike, canopy temperature depression at 15 days after anthesis and grain yield plant^{-1}; similarly, moderate PCV estimates were recorded for biological yield plant^{-1}, 1000-grain weight, peduncle length, canopy temperature depression at anthesis, spike length, grain filling duration, normalized difference vegetation index at 15 days after anthesis, SPAD chlorophyll content at 15 days after anthesis, harvest index and number of effective tillers per plant. The traits viz., SPAD chlorophyll content at anthesis, plant height, days to heading, normalized difference vegetation index at anthesis and days to maturity exhibited low estimates of phenotypic coefficient of variation. Similar results have also been delineated by Matin *et al*. (2019), Hailu *et al*. (2016), Shiferaw *et al*. (2020) and Devi *et al*. (2020) for number of grains per spike, grain yield, and spike length; Tahar *et al*. (2015) for grain filling duration, number of effective tillers, days to heading and maturity; Kumar and Sehrawat (2021) for peduncle length, and biological yield; Akgun (2016) for 1000-grain weight, plant height, and SPAD chlorophyll content at anthesis; Shehrawat and Kumar

Table 3. Genetic variability parameters for different traits in barley under heat stress condition

Traits	Mean	Range	PCV (%)	GCV (%)	Heritability (bs)(%)	GA (% mean)
DH	77.17	73.00 - 82.67	3.14	2.91	85.97	5.55
DM	109.65	106.67 - 113.33	1.87	1.48	62.55	2.41
GFD	23.39	18.33 - 27.67	11.73	9.60	67.00	16.19
ETP	15.43	11.56 - 18.75	11.22	7.83	48.70	11.26
PH	92.70	82.78 - 106.44	8.68	6.76	50.09	1.80
PL	8.67	5.90 - 12.26	18.91	16.24	73.83	28.75
SL	7.54	5.50 - 10.14	15.34	9.52	38.53	12.18
GPS	45.17	24.09 – 74.67	41.69	41.15	97.45	83.69
TGW	35.75	28.83 – 43.17	14.67	8.91	36.89	11.15
BYP	46.30	35.27 - 62.42	13.78	12.96	88.41	25.09
HI	43.24	32.32 – 49.39	12.91	9.56	54.82	14.58
GYP	20.56	15.27 - 26.13	13.94	11.55	68.70	19.72
SPAD 1	44.79	28.82 - 50.50	9.29	8.01	74.26	14.21
SPAD2	37.82	33.00 - 44.02	9.98	6.47	42.06	8.64
NDVI 1	0.76	0.70 - 0.82	5.14	2.04	15.74	1.67
NDVI 2	0.65	0.51 - 0.79	9.77	9.23	89.35	17.97
CTD1	3.72	2.36 - 4.75	13.97	12.13	75.48	21.72
CTD 2	1.83	0.42 - 2.97	28.74	25.33	77.67	45.98

DH: Days to heading, DM: Days to maturity, GFD: Grain filling duration, ETP: Number of effective tillers per plant, PH: Plant height, PL: Peduncle length, SL: Spike length, GPS: Number of grains per spike, TGW: 1000-grain weight, BYP: Biological yield per plant, HI: Harvest index, GYP: Grain yield per plant, SPAD 1: Chlorophyll content (SPAD) at anthesis, SPAD 2: Chlorophyll content (SPAD) at 15 days after anthesis, NDVI 1: Normalized difference vegetation index at anthesis, NDVI 2: Normalized difference vegetation index at 15 days after anthesis, CTD 1: Canopy temperature depression at anthesis, CTD 2: Canopy temperature depression at 15 days after anthesis

(2021) for harvest index, SPAD chlorophyll content at 15 days after anthesis, and normalized difference vegetation index at anthesis.

The perusal of data under heat stress found high PCV estimates for number of grains per spike and canopy temperature depression at 15 days after anthesis, however, the estimates of PCV were observed moderate for peduncle length, spike length, 1000-grain weight, canopy temperature depression at anthesis, grain yield per plant, biological yield per plant, harvest index, grain filling duration and number of effective tillers per plant. Characters possessed low estimates of PCV under stress condition includes SPAD chlorophyll content at 15 days after anthesis, normalized difference vegetation index at 15 days after anthesis, SPAD chlorophyll content anthesis, plant height, normalized difference vegetation index at anthesis, days to heading and days to maturity. Similar results were also imitated in the findings of Shehrawat and Kumar (2021) for traits viz., grain filling duration, number of effective tillers, peduncle length, harvest index, normalized difference vegetation index at anthesis and normalized difference vegetation index at 15 days after anthesis; and Devi *et al*. (2020) for number of grain per spike, spike length, 1000-grain weight, days to heading and maturity.

Heritability : The heritability is quite important for plant breeder to predict the response to selection and to assess the usefulness and precision of results from cultivar testing and screening trials. Heritability in broad sense as expressed in per cent varied from 27.61% to 97.71% under normal sown and 15.74% to 97.45% under stress condition, respectively. High heritability was recorded for number of grains per spike followed by 1000-grain weight, biological yield per plant, grain yield per plant, days to heading, SPAD chlorophyll content at anthesis and peduncle length. Moderate heritability was found for normalized difference vegetation index at 15 days after anthesis, plant height, grain filling duration, number of effective tillers per plant, normalized difference vegetation index at anthesis, canopy temperature depression at anthesis, spike length, canopy temperature depression at 15 days after anthesis and SPAD chlorophyll content at 15 days after anthesis. Days to maturity and harvest index showed low estimates of heritability. These findings were further validated by the results of Sunil *et al*. (2017), Shehrawat and Kumar (2021), Shehrawat *et al*. (2021) for days to heading, peduncle length, number of grains per spike, 1000-grain weight, biological yield, and grain yield; Tahar *et al*. (2015) for number of effective tillers, plant height, spike length, and harvest index; Matin *et al*. (2019) for days to maturity and Shrimali *et al*. (2017) for SPAD chlorophyll content at anthesis.

Under stress condition, number of grains per spike, normalized difference vegetation index at 15 days after anthesis, biological yield per plant, days to heading, canopy temperature depression at 15 days after anthesis, canopy temperature depression at anthesis, SPAD chlorophyll content at anthesis, peduncle length, grain yield per plant, grain filling duration and days to maturity showed high estimates of heritability, however, moderate heritability was found for harvest index, plant height and number of effective tillers per plant and SPAD chlorophyll content at 15 days after anthesis. The traits that had low heritability estimates were spike length, 1000-grain weight and normalized difference vegetation index at anthesis. Similar observations were also substantiated for grain filling duration, peduncle length, SPAD chlorophyll content at anthesis, normalized difference vegetation index at 15 days after anthesis, canopy temperature depression at anthesis and at 15 days after anthesis by Shehrawat and Kumar (2021) and for days to heading and maturity, number of grains per

spike, biological yield, grain yield, and plant height by Devi *et al*. (2020).

Genetic advance as percent of mean : The highest and lowest estimates of genetic advance as percent of mean under normal sown were 81.74% and 1.04%, respectively, while these estimates were 83.69% and 1.67% under stress environment. The results of genetic advance under normal sown condition indicated high estimates for number of grains spike^{-1}, grain yield plant^{-1}, biological yield plant^{-1}, 1000-grain weight and canopy temperature at 15 days after anthesis, while, the traits *viz*., peduncle length, canopy temperature depression at anthesis, plant height, SPAD chlorophyll content at anthesis, grain filling duration and number of effective tillers plant^{-1} recorded with moderate genetic advance. The findings also showed low estimates of genetic advance for SPAD chlorophyll content at 15 days after anthesis, spike length, harvest index, days to heading, normalized difference vegetation index at 15 days after anthesis, normalized difference vegetation index at anthesis and days to maturity. These results are in line with the observations of Sunil *et al*. (2017), Tahar *et al*. (2015) and Shiferaw *et al*. (2020) for number of grains per spike, biological yield, grain yield, and plant height; Shrimali *et al*. (2017) for days to heading and maturity; Katiyar *et al*. (2020) for number of effective tillers and harvest index; Shehrawat and Kumar (2021) and Shehrawat *et al*. (2021) for grain filling duration, SPAD chlorophyll content at anthesis and canopy temperature depression at anthesis; Almohisen *et al*. (2021) for spike length and Akgun (2016) for 1000-grain weight and SPAD chlorophyll content at 15 days after anthesis.

The traits namely, number of grains per spike, canopy temperature at 15 days after anthesis, peduncle length, biological yield per plant and canopy temperature depression at anthesis under stress condition have high estimates of genetic advance. Similarly, the characters like grain yield per plant, normalized difference vegetation index at 15 day after anthesis, grain filling duration, harvest index, SPAD chlorophyll content at anthesis, spike length, number of effective tillers per plant, 1000-grain weight have moderate genetic advance. But the genetic advance observed was low for SPAD chlorophyll content at 15 days after anthesis, days to heading, days to maturity, plant height, normalized difference vegetation index at anthesis under heat stress. These recorded results were also corroborated by findings of Devi *et al*. (2020) for number of grains per spike, biological yield, spike length, and days to maturity; Shehrawat and Kumar (2021) for peduncle length, grain filling duration, number of effective tillers, SPAD chlorophyll content at anthesis, normalized difference vegetation index at 15 days after anthesis and days to heading. Yadav *et al*. (2015) also reported wide range, high coefficients of variation, heritability and genetic advance as percent of mean for grain yield, tillers per plant and number of grains per spike in barley.

High heritability coupled with genetic advance was observed for number of grains per spike, 1000-grain weight, biological yield per plant and grain yield per plant under normal sown. The results found are in agreement with the previous studies of Shehrawat *et al*. (2021) and Shiferaw *et al*. (2018). Similarly, under heat stress the traits viz., peduncle length, number of grains per spike, biological yield per plant and canopy temperature depression at anthesis and at 15 day after anthesis exhibited high heritability with high genetic advance. This finding can be compared and interpreted in context to the studies of Devi *et al*. (2020), and Shehrawat and Kumar (2021).The results of the current investigation could be promising for a breeder who is chiefly concerned with developing barley cultivars for heat stress tolerance.

Conclusion

The results of phenotypic and genotypic coefficient of variation under both environments revealed high estimates for number of grains per spike; moderate estimates for peduncle length, biological yield plant^{-1} and canopy temperature depression at anthesis. However, days to heading and maturity, plant height, SPAD chlorophyll content at anthesis and normalized difference vegetation index at anthesis exhibited low estimates of phenotypic and genotypic coefficient of variation under normal as well as under heat stress conditions.

High heritability coupled with genetic advance was observed for number of grains per spike, 1000-grain weight, biological yield plant^{-1} and grain yield per plant under normal sown similarly, under heat stress the traits *viz*., peduncle length, number of grains per spike, biological yield plant^{-1} and canopy temperature depression at anthesis and at 15 day after anthesis exhibited high heritability with high genetic advance, indicates the importance of these traits in selection and crop improvement. Consequently, it is suggested that the parameters with high heritability coupled with high genetic advance can be considered as key component traits while setting the selection criterion for barley improvement for timely sown and heat stress conditions.

Acknowledgement

The authors' expresses sincere gratitude to Head, Department of Genetics and Plant Breeding, College of Agriculture, CCS Haryana Agricultural University, Hisar-125004 for providing research facilities.

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