The Pharma Innovation Journal 2021; 10(12): 707-711

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(12): 707-711

www.thepharmajournal.com
Received: 03-09-2021
Accepted: 25-10-2021

BS Meena
Research Scholar, Department of Genetics & Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Abhay Dashora
Assistant Professor, Department of Genetics & Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

NS Dodiya
Professor, Department of Genetics & Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Urmila
Tech. Assistant Department of Genetics & Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Corresponding Author:
BS Meena
Research Scholar, Department of Genetics & Plant Breeding, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan, India

Phenotypic stability for grain yield and its component traits in six rowed barley (*Hordeum vulgare* L.)

BS Meena, Abhay Dashora, NS Dodiya and Urmila

Abstract
Stability performance of 15 F_1's progeny of barley along with 8 parents and 2 checks were evaluated under three environments (E_1, E_2 & E_3) created by three dates of sowing *viz.*, E_1 (Early sowing) E_2 (Normal sowing) and E_3 (late sowing). The experiment was laid out in Randomized Block Design with three replications at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan during *Rabi* 2020-21. Significant differences were observed among the genotypes for all the traits studied. Mean sum of square due to environment + genotype x environment interactions (E + G x E) revealed that genotype interacted considerably with environmental conditions. Further, partitioning of E + G x E effects indicated that E (linear), G x E (linear) components were highly significant for grain yield per plant, days to maturity, tillers per plant, numbers of grains per spike and test weight. Genotype IBON HI 19-82 and F_1's *viz*., IBON HI 19-94 x RD 2899 and IBON HI 19-82 x RD 2035 had high mean value than general mean for grain yield per plant (g), tillers per plant, grains per spike, test weight (g), coupled with regression coefficient close to unity bi=1 and deviation from regression (S^2d_1=0) non-significant identified as most stable and desirable barley genotypes. The use of stable cultivars with higher yield and quality traits is needed to increase the area and productivity under barley. When cultivars are tested in terms of grain yield at the multi-environmental trials, great differences are commonly observed in yield performance over environments. High yield performance with high stability might increase phenotypic stability to the next progenies and obtained transgressive segregants for better adaptability to environment condition.

Keywords: Barley, G x E interaction, grain yield, phenotypic stability

Introduction
Barley (*Hordeum vulgare* L.) is one of the ancient cereal crops, currently ranking fourth after rice, wheat and maize in the world production. It can be grown in wide range of environments than any other cereals, Includ extreme of latitude, longitude and high altitude (Kishore *et al*., 2016) [13]. Barley is a nutri-rich cereal and occupies an area of 0.60 million hectare with a production and productivity of 1.818 million tones and 29.88 q/ha (Anonymous, 2021) [3]. In the global context, only 2-5 per cent of barley is used as human food, while nearly 20-25 percent of the produce is consumed by malting industry and 75-80 percent is used for livestock purpose, and remaining percentage is used for medicinal purpose, brewing baby foods, *etc*. (Caterina *et al*., 2018) [5].
Barley cultivation requires less input in the form of fertilizer, irrigation and insecticides and it has potential to grow under drought and saline conditions (Baik and Ullrich, 2008). The productivity of barley is stagnant in the country and below the world barley productivity on account of its cultivation under marginal lands, minimum input management conditions and slow varietal replacement rate.
The barley production and productivity can be improved through identification and introduction of stable and adaptive cultivars. Plant breeder continuously strives to enhance yield as well as broaden the genetic base of a crop to prevent its vulnerability to changing environments. The differential yield response of cultivars from one environment to another is called Genotype x Environment (G x E) interaction (Allard, 1960; Vargas *et al.*,1998) [2, 10] and it is of much value in the selection of better genotypes (Raffi *et al*., 2004) [17]. Hence, the interaction of cultivar with environmental factors is a prime consideration for plant breeders. G × E interaction help in restructuring the programme to minimize the interaction effect, or exploit it to produce varieties with specific adaptation to particular environments (Eisemann *et al*., 1990) [10].

Therefore, the present investigation was made to estimate phenotypic stability for yield and yield attributing traits in 25 barley genotypes, comprising of released and newly developed promising genotypes, under varying environmental conditions.

Materials and Methods

The experimental materials used for the present study was developed by crossing 07 six-rowed barley lines with 05 testers in L x T fashion during 2019-20. The materials received from AICRP, Wheat and Barley, Department of Genetics and Plant Breeding, RCA, Udaipur. A total of 35 F_1's were generated, out of which 15 F_1's were evaluated along with 8 parents *viz*., IBON-HI-19-82, IBON -HI-19-111, IBON-HI-19-81, GSBYT-19-1, GSBYT-19-6, RD-2552 (T), RD-2786 (T), RD-2899 (T) and 2 checks *viz*., DWRB-137 and BH-946 at Instructional Farm, Rajasthan College of Agriculture, MPUAT, Udaipur in Randomized Block Design with three replications in three different environments, which were created by using three dates of sowing *viz*, Early sowing (E_1), Normal sowing (E_2), Late sowing (E_3) during *rabi* 2020-21.

Table 1: The details of three environments

Environment	Date of sowing
E1 (Early Sowing)	November 01, 2020
E2 (Normal sowing)	November 20, 2020
E3 (Late sowing)	December 04, 2020

Each genotype was grown in single row of 2 m length with a spacing of 30 cm. All the recommended cultural and agronomic practices were followed to raise the healthy crop. Five randomly selected plants per plot per replication in each genotype were labeled and observations were recorded for days to maturity, tillers per plant, grains per spike, test weight (g) and grain yield per plant (g). The data were subjected to estimate phenotypic stability of genotypes for yield and its attributing traits as per the model proposed by Eberhart and Russell (1966) [9].

The analysis of this statistical model is as follows

$$Y_{ij} = \mu_i + \beta i I_j + \delta_{ij}$$

Where

Y_{ij} = Mean performance of i^{th} genotype in j^{th} environment

μ_i = Mean of i^{th} genotype over the environments

βi = Regression coefficient i^{th} genotype

δ_{ij} = Deviation from regression of i^{th} genotype in j^{th} environment

I_j = The environment index for j^{th} environment which is defined as the deviation of the mean of all the genotypes at a given environment from the overall mean.

$$= \frac{\sum_i Y_{ij}}{t} - \frac{\sum_i \sum_j Y_{ij}}{ts}$$

A stable genotype is one with high mean coupled with unit regression coefficient (b = 1) and the deviation not significantly differing from zero (S^2di = 0).

Results and Discussion

In present investigation, the pooled analysis of variance for different characters is presented in Table 2. The mean sum of squares due to genotypes was found significant for all characters under study indicating the presence of sufficient variability for these traits. Lodhi *et al*. (2015) [14] observed significant differences among barley genotypes for all the traits under study over all 3 individual environments. According to this model the genotype x environment interaction was further partitioned into linear and non-linear components. The significant G x E observed for all the characters under study indicated that characters are unstable and may considerably fluctuate with environment change. The same was earlier reported by Chand *et al*. (2008) [6], Kavitha *et al*. (2009) [12], Lodhi *et al*. (2015) [14] and Fatma *et al*. (2018) [11]. The environments (linear) were significant against pooled deviations for all the characters, whereas genotype x environment (linear) was found to be significant against pooled deviation for days to maturity, tillers per plant, grains per spike, test weight and grain yield per plant. The results indicated that variation in performance of these genotypes is predictable, when grown over these environments. The variation due to pooled deviation was significant for all the characters studied, which indicated that genotypes differed with respect to their stability. These results are in accordance with the study of Yadav *et al*., 2019 [20], Lodhi *et al*., 2015 [14] and Verma *et al*., *2016* [19]. Eberhart and Russell's model is one of the best techniques used to rank the genotypes for stability. According to model, genotypes with high mean (µ) performance, a regression coefficient of unity (bi=1), minimum deviation from regression (S^2di=0) exhibit better general adaptability across environments and are considered as a stable one. Where βi>1, the genotype is responsive to favorable environment. If βi<1, the genotype performs well despite an unfavorable environment. All the three parameters of stability for five traits are presented in Table 3.

Grain yield per plant

The stability analysis for grain yield per plant revealed that the parents depicted non-significant deviation from regression (S^2di), were stable and predictable for grain yield per plant. Among the parents, IBON HI 19-82 (26.71) had lower mean value for grain yield per plant, close to unity of regression coefficient (bi =1) and non-significant deviation from regression (S^2di=0) indicating that the parent exhibited more phenotypic stable, but adapted to poor environments condition. Parents IBON HI 19-81, GSBYT 19-6, RD 2899 and BH 946 have lower mean value than population mean (27.25), regression coefficient lower than unity (bi >1) and non-significant deviation from regression (S^2di=0), it showed that the parents responsive to unfavorable environments. Out of 15 crosses, two crosses namely IBON HI 19-94 x RD 2899 and IBON HI 19-82 x RD 2035 were identified desirable and stable for grain yield per plant as they have high mean value, close to unity of regression coefficient (bi =1) and non-significant deviation from regression (S^2di=0) indicating that they exhibited more phenotypic stable to across the environments condition for grain yield. Similar results were reported for grain yield by Fatma, *et al*. (2018) [11], Lodhi *et al*. (2015) [14], Yadav *et al*. (2019) [20] and Pilania and Dhaka (2007) [16]. Crosses IBON HI 19-82 x RD 2715 had higher mean grain yield, regression coefficient greater than unity (bi>1), indicating that the crosses are unstable to studied environmental condition. IBON HI 19-110 x RD 2786 had higher mean value, low bi value to unity (bi<1) and non-significant deviation from regression (S^2di=0), indicated that adapted to poor environmental conditions. All the three parameters of stability for grain yield are presented in fig 1.

Days to maturity

Among the parents, IBON-HI 19-82, IBON-HI 19-111, GSBYT 19-1 and RD 2552 identified suitable for medium maturity under poor environmental condition, as they had lower mean performance than average value (121.40), low regression coefficient than unity (bi<1) and non-significant deviation from regression. Crosses IBON HI 19-82 x RD 2035, IBON HI 19-82 x RD 2715, IBON HI 19-111 x RD 2035 and GSBYT 19-6 x RD 2035 expressed suitable for medium maturity in poor environments as they have low mean value than average value, low bi value to unity (bi<1) and non-significant deviation from regression (S^2di=0). The significant genotype x environment interaction has been reported for days to maturity by Costa and Bollero (2001) [7] and Lodhi *et al.* (2015) [14].

Tillers per plant

Among the parents, IBON HI 19-82, RD 2786 and RD 2899 were found stable and widely adapted for tillers per plant over environments, as they have high mean value then parental population mean (9.27), regression coefficient close to unity (bi=1) and minimum deviation from regression (S^2di=0). RD 2552 adapted to poor environment and IBON HI -19-81 expressed to rich environment, as they have high mean value, low regression coefficient (bi<1) and high regression coefficient (bi.>1) than unity, non-significant deviation from regression. Among crosses, IBON HI -19-94 x RD 2899 and IBON HI 19-82 x RD 2035 have high mean value, regression coefficient close to unity (bi =1) and non-significant deviation from regression (S^2di) showed its stability for trait under the tested environments. IBON HI 19-94 x RD 2786, IBON HI -110 x RD 2552, IBON HI -110 x RD 2786, IBON HI -111 x RD 2715 and IBON HI -81 x RD 2715 adapted to rich environment, as they have high mean value, high regression coefficient (bi.>1) than unity and non-significant deviation from regression. Similar findings were reported by Megahed *et al.* (2019) and Lodhi *et al.* (2015) [14]. Crosses IBON HI 19-94 x RD 2552, IBON HI 19-110 x RD 2899, IBON HI 19-111 x RD 2035 and IBON HI 19-1 x RD 2035 were found unstable for the trait as, they have high tillers yielding, but their corresponding "bi" value significantly lower than unity and highly significant deviation from regression ((S^2di).

Grains per spike

Among the parents, IBON HI 19-82 was found stable and widely adapted for all environments with higher mean value i.e. 59.31, regression coefficient to unity (bi=1) and non-significant deviation from regression. Cross IBON HI 19-82 x RD 2035 and GSBYT 19-6 x RD 2715 expressed stability across environment conditions for grains per spike, as they have higher mean value then population mean (53.54), close to unity of regression coefficient (bi=1) and minimum deviation from regression coefficient (S^2di=0). Cross IBON HI 19-94 x RD 2899, IBON HI 19-110 x RD 2786, IBON HI 19-82 x RD 2715, GSBYT 19-6 x RD 2035 and GSBYT 19-1 x RD 2715 found suitable for favourable environment, as they have higher mean value, regression coefficient greater than unity (bi<1) and non-significant deviation from regression. GSBYT 19-1 x RD 2035 expressed under poor environment condition, as it had higher mean value, lower regression coefficient than unity (bi<1) and non-significant deviation from regression. Similar results were reported by Lodhi *et al*. (2015) [14].

Test weight

Genotype IBON HI 19-82 was found comparatively stable as its had high mean value than population mean (46.31), low regression coefficient than unity (bi =0.73) and non-significant deviation from regression for the trait, it's suggested that genotype is stable and adapted for poor environment. Parents RD 2552, RD 2786 and RD 2899 expressed stability under favourable environment as they had higher mean value, regression coefficient (bi>1) greater than unity and non-significant deviation from regression for the test weight. IBON HI 19-94 x RD 2899 and IBON HI 19-110 x RD 2786 were found most stable crosses, as they had higher mean value than population mean (46.31), regression coefficient (bi=1) close to unity, and non-significant deviation from regression. Crosses IBON HI 19-111 x RD 2715 and GSBYT 19-6 x RD 2035 had higher mean value, regression coefficient lower to unity (bi<1) and non-significant deviation from regression (S^2di =0) as they expressed perform well despite under unfavorable environment. IBON HI 19-82 x RD 2035 and IBON HI 19-81 x RD 2715 exhibited above average stable and adapted to rich environment, as they had higher mean value, regression coefficient (bi>1) greater than unity and S^2di=0 for test weight. Pilania and Dhaka (2007) [16] reported that eight genotypes, showing better response to favorable environments as they had b = >1. Similarly, twelve genotypes having b = <1 showing least response to the environments.

Conclusion

Pooled analysis of variance for stability revealed that parents IBON HI 19-82 had regression coefficient around unity (bi=1) with high mean value than population mean indicated its suitability and stable performance under varies environments for grain yield per plant, grains per spike and tillers per plant. Parents RD 2786 showed high mean with regression coefficient value greater than unity (bi>1) indicated adaptability to favorable environments for tillers per plant, grains per spike and test weight.

Over all study on grain yield and its attributing traits, it was observed that the F_1's *viz.*, IBON HI 19-94 x RD 2899 and IBON HI 19-82 x RD 2035 found stable for grain yield per plant also depicted stability in respect of its one or more yield component traits like tillers per plant, and test weight indicated that the stability of various component traits might be responsible for the observed stability of different F_1's for grain yield per plant. High performance and high stability might transmit high means and increased phenotypic stability to the next progenies and obtained transgressive segregants for better adaptability to environment condition. The ideal genotype may consider for developing improved phenotypic stable barley varieties.

Table 2: Analysis of variance for grain yield and its attributing traits in barley

Source of variation	df	Days to Maturity	Tillers / plant	Grains per spike	Test weight (g)	Grain yield / plant (g)
Variety	24	43.69**	6.55**	113.61**	20.69**	260.24**
Env. + (G X E)	50	25.31**	0.94**	13.44**	8.48**	10.27**
Env. linear	1	638.68**	7.31**	111.88**	169.94**	97.13**

G X E linear	24	17.12*	1.16*	15.29*	6.66*	11.79**
Pooled deviation	25	8.63**	0.48**	7.73**	3.76**	5.33**
Pooled error	150	0.664	0.155	3.195	1.403	1.720

* Significant at 5% level and ** significant at 1% level.

Table 3: Stability parameters of yield following joint regression analysis (Eberhart and Russell, 1966) [9]

SN	Genotype	Grain yield / plant (g)			Days to maturity			Tillers per plant		
		µ	**bi**	**$\bar{S}2d1$**	**µ**	**bi**	**$\bar{S}2d1$**	**µ**	**bi**	**$\bar{S}2d1$**
1	IBON-HI-19-82	26.71	0.99	-0.816	118.89	0.28	-0.604	9.82	1.02	0.185
2	IBON -HI-19-111	23.90	1.41	-1.466	118.89	0.42	-0.255	9.29	0.13	0.056
3	IBON-HI-19-81	24.06	0.94	-1.649	118.78	-0.08	13.919**	9.63	1.51	-0.075
4	GSBYT-19-1	19.96	1.02	7.826*	120.89	0.84	0.349	8.92	-0.23	-0.135
5	GSBYT-19-6	13.68	0.56	1.648	118.67	0.52	7.215**	8.11	0.39	0.070
6	RD-2552	27.74	-0.19	2.023	119.11	0.29	3.957	9.97	0.25	0.376
7	RD-2786	25.56	0.91	10.986**	120.44	1.12*	-0.475	9.47	1.01	-0.115
8	RD-2899	26.22	-0.76	3.981	121.89	0.94	0.330	9.79	1.00	0.244
9	DWRB-137	24.84	3.20	14.795**	115.33	0.76	4.981*	9.04	-0.30	0.265
10	BH 946	20.78	-1.07	-1.388	119.33	0.71	12.332**	8.67	-0.37	1.441**
11	IBON-HI-19-94 x RD 2552	21.98	-2.54*	-1.176	127.89	2.03*	41.064**	10.23	-2.89*	0.871*
12	IBON-HI-19-94 x RD 2786	25.58	-0.44	-1.720	126.00	1.52*	20.872**	11.33	1.76	-0.013
13	IBON-HI-19-94 x RD 2899	51.67	1.00	2.308	129.11	1.02	3.358	14.57	1.00	-0.142
14	IBON-HI-19-110 x RD 2552	23.68	1.97	2.423	127.78	1.72*	5.497**	11.37	1.40	0.096
15	IBON-HI-19-110 x RD 2786	47.12	2.12	-1.116	127.67	2.04*	6.359**	12.35	3.92	-0.154
16	IBON-HI-19-110 x RD 2899	27.40	0.12	10.771**	127.00	2.27**	14.526**	10.93	-0.52	0.522*
17	IBON-HI-19-82 x RD 2035	52.20	0.99	-1.701	118.33	0.65	0.111	13.39	1.01	0.341
18	IBON-HI-19-82 X RD 2715	30.99	4.34	20.187**	120.67	0.98	0.610	10.35	2.58	0.357
19	IBON-HI-19-111 x RD 2035	23.62	-2.13*	0.386	120.56	0.14	-0.641	11.08	-3.97**	1.948**
20	IBON-HI-19-111 x RD 2715	21.61	1.91	11.020**	120.22	-0.38	8.078**	11.03	1.52	0.026
21	IBON-HI-19-81 x RD 2715	23.88	-0.90	1.457	119.78	-0.01	11.850**	11.39	1.36	-0.065
22	GSBYT-19-6 x RD 2715	21.46	2.39	-0.713	117.00	1.27	11.940**	9.00	1.37	0.795*
23	GSBYT-19-6 x RD 2035	25.91	2.37	4.818	120.00	0.88	1.056	10.04	1.92	1.328**
24	GSBYT-19-1 x RD 2035	26.45	3.93	8.676*	121.56	2.49**	13.052	11.07	4.84*	-0.100
25	GSBYT-19-1 x RD 2715	24.45	2.86	-1.399	119.22	2.58**	19.683**	10.71	5.30**	-0.119
General Mean		27.25			121.40			10.46		

* Significant at 5% level and ** significant at 1% level.

Table 3: Stability parameters of yield following joint regression analysis (Eberhart and Russell, 1966) [9]

SN	Genotype	Grains per spike			Test weight (g)		
		µ	**bi**	**$\bar{S}^2d_1$**	µ	bi	$\bar{S}^2d_1$
1	IBON-HI-19-82	59.31	1.00	-2.627	48.20	0.73	3.421
2	IBON -HI-19-111	50.94	0.85	30.345**	42.94	1.85*	1.013
3	IBON-HI-19-81	48.01	0.23	10.190*	46.98	-0.70	11.161**
4	GSBYT-19-1	45.58	1.07	0.026	41.61	-0.01	1.040
5	GSBYT-19-6	51.21	-0.73	4.701	41.66	0.81	0.056
6	RD-2552	49.74	-1.13	-2.528	49.32	1.35	-1.302
7	RD-2786	56.06	1.11	5.457	49.91	1.12	2.723
8	RD-2899	45.86	-0.78	0.073	49.84	1.12	-1.059
9	DWRB-137	49.38	0.31	15.432*	48.87	1.48	5.436*
10	BH 946	51.41	0.08	17.753*	45.46	1.28	-0.345
11	IBON-HI-19-94 X RD 2552	50.94	-3.20	-0.494	48.01	2.39**	9.409**
12	IBON-HI-19-94 X RD 2786	60.88	3.74	14.161*	44.20	1.58	0.621
13	IBON-HI-19-94 X RD 2899	58.47	1.80	-2.770	48.73	1.01	2.022
14	IBON-HI-19-110 X RD 2552	48.87	-0.17	10.361*	44.07	0.20	0.253
15	IBON-HI-19-110 X RD 2786	56.66	4.46	-2.087	48.73	1.01	-1.159
16	IBON-HI-19-110 X RD 2899	44.21	-0.27	-2.851	44.21	-0.61	5.414*
17	IBON-HI-19-82 X RD 2035	54.18	-0.30	11.227*	47.62	1.68	-0.743
18	IBON-HI-19-82 X RD 2715	55.48	2.43	-1.977	43.56	1.52	2.277
19	IBON-HI-19-111 X RD 2035	47.90	-0.23	-3.176	47.29	-0.19	5.186*
20	IBON-HI-19-111 X RD 2715	45.32	1.99	0.868	47.57	0.22	-1.182
21	IBON-HI-19-81 X RD 2715	58.58	3.21	14.937*	48.80	1.39	3.489
22	GSBYT-19-6 X RD 2715	63.45	1.04	-2.790	44.09	1.25	2.983
23	GSBYT-19-6 X RD 2035	65.04	3.31	4.376	46.51	-0.34	3.848
24	GSBYT-19-1 X RD 2035	62.28	0.71	-2.055	42.70	1.01	5.568*
25	GSBYT-19-1 X RD 2715	58.86	4.47	-3.087	46.61	3.84**	-0.467
General Mean		53.54			46.31		

* Significant at 5% level and ** significant at 1% level.

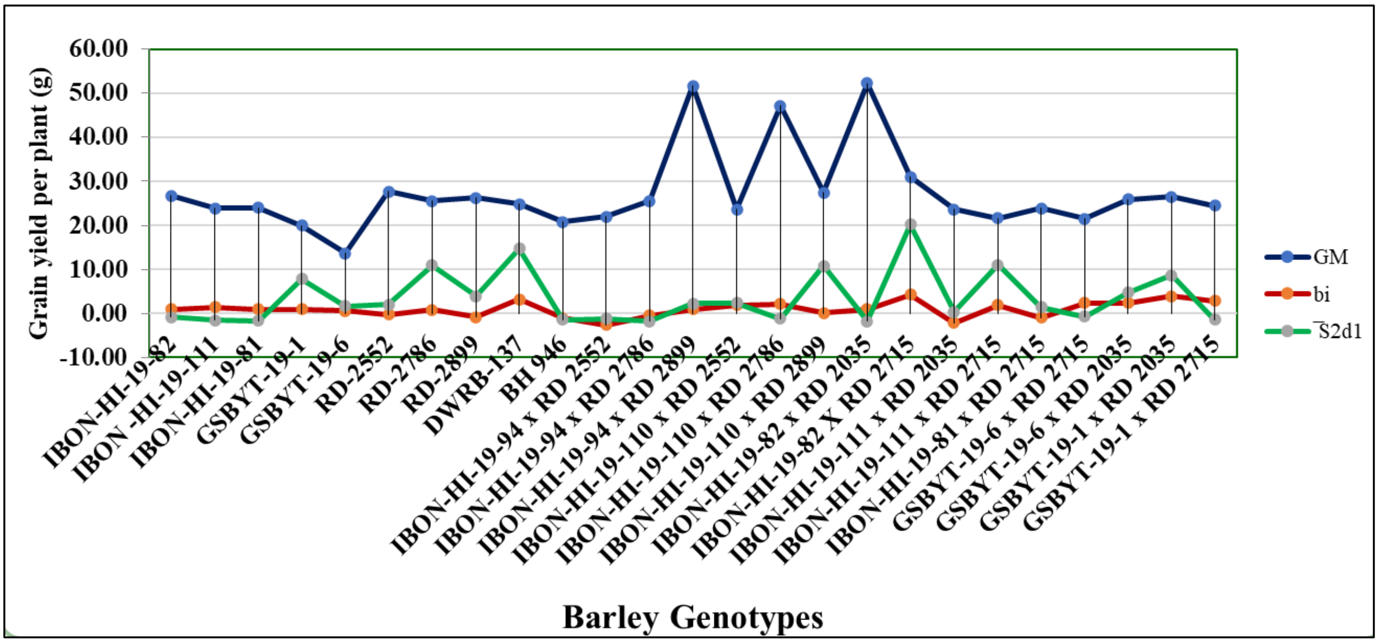

Fig 1: Stability parameters of yield following joint regression analysis (Eberhart and Russell, 1966) [9]

Acknowledgment

The Authors are thankful to the Director, ICAR-Indian Institute of Wheat and Barley Research, Karnal, Haryana for providing the seed materials for research along with the Director Research, DOR, MPUAT, Udaipur for providing facility for research works.

References

1. Ahmad J, Choudhry MH, Salah-ud-Din S, Ali MA. Stability for grain yield in wheat. Pak. J. Bot. 1996;28:61-65.
2. Allard RW. Principles of Plant Breeding. 2nd Edn. New York: John Willey and Sons 1960.
3. Anonymous. Progress Report of AICRP Wheat and Barley Barley Improvement, ICAR- IIWBR, Karnal, India 2020-2021;1(1).
4. Baik KB, Ullrich ES. Barley for food: characteristics, improvement and renewed interest. Journal of Cereal Science 2008;48:233-242.
5. Caterina T, Vera A, Emilia L, Roberto LR. Economic Analysis of the Barley Market and Related Uses, Department of Economics, University of Foggia, Italy 2018, 34.
6. Chand N, Vishwakarma SR, Verma OP, Kumar M. Phenotypic stability of elite barley lines over heterogeneous environments. Barley Genet. Newsletter, 2008;38:14-17.
7. Coasta JM, Bollero GA. Stability analysis of barley for grain yield in the US Mid-Atlantic region. Ann. Applied Biol 2001;139**:**137-143.
8. Crossa J. Statistical analyses of multi-location trials. Adv. Agron 1990;44:55-85.
9. Eberhart SA, Russell WA. Stability parameters for comparing varieties. Crop Science, 1996;16:36-40.
10. Eisemann RL, Cooper M, Woodruff DR. Beyond the analytical methodology-better interpretation of genotype-by-environment interaction. In: Kang MS (ed) Genotype-by-environment interaction and plant breeding 1990.
11. Fatma MA, Megahed AA, El-Khawaga AA, Ali MMA, Hassan AIA. Stability analysis of barley genotypes under different water stress levels. Zagazig J. Agric. Res 2018;45:1521-1545.
12. Kavitha G, Dhindsa GS, Singh S, Singh J. Stability analysis of yield and its components in malt barley (*Hordeum vulgare* L.) genotypes. Crop Improvement, 2009;36:29-34.
13. Kishore N, Kumar V, Verma RPS. Barley. In: Singh M., Kumar S. (eds) Broadening the Genetic Base of Grain Cereals. Springer, New Delhi 2016 https://doi.org/10.1007/978-81-322-3613-9 5.
14. Lodhi RD, Prasad LC, Bornare SS, Madakemohekar AH, Prasad R. Stability analysis of yield and its component traits of barley (*Hordeum vulgare* L.) genotypes in multi-environment trials in the north eastern plains of India. SABRAO Journal of Breeding and Genetics 2015;47:143-159.
15. Piepho HP, Methods for comparing the yield stability of cropping systems- a review. Journal of Agronomy Crop Sci 1998;180:193-213.
16. Pilania DS, Dhaka RPS. Stability analysis for grain yield and quality parameters in barley (*Hordeum vulgare* L.) germplasm. International journal of agricultural Science, 2007;3:49-52.
17. Raffi SA, Newaz MA, Khan N. Stability analysis for pod and seed production in dry beans (*Phaseolus vulgaris* L.). Asian J. Plant Sci 2004;3:239-242.
18. Vargas M, Crossa J, Sayre K, Reynolds M, Ramirez M, Talbot M. Interpreting genotype x interaction in wheat by partial least squares regression. Crop Sci 1998;38:679-689.
19. Verma RPS, Kharab AS, Kumar V, Verma A. G × E evaluation of salinity tolerant barley genotypes by AMMI model. Agriculture Science of Digest 2016;36:191-196.
20. Yadav OP, Razdan AK, Kumar B. Genotype by environment interaction and stability analysis of grain yield in barley (*Hordeum vulgare* L.) Journal of Pharmacognosy and Phytochemistry 2019;8:686-688.