Research Article

Stability Analysis of Advanced Chilli Lines

Hidayatullah[1*], Sammia Mahroof[1], Saleem Abid[2], Naveeda Anjum[3], Noor Habib[4], Akhter Saeed[5] and Muhammad Arshad Farooq[1]

[1]Vegetable Crops Research Crops Research Programme, Horticultural Research Institute, National Agricultural Research Centre Islamabad, Pakistan; [2]Statistics and Computing Programme, Social Sciences Research Institute National Agricultural Research Centre Islamabad; Pakistan; [3]Barani Agricultural Research Institute, Chakwal, Pakistan; [4]Vegetable Botany Section, Agricultural Research Institute, Swat, Pakistan; [5]Vegetable Research Institute, Ayub Agricultural Research Institute, Faisalabad; Pakistan.

Abstract | Chillies enriched with Vitamin C and beta-carotene, traditionally are the integral part of daily food in Pakistan. Like any other agricultural produce, chillies too have been greatly affected by erratic environmental conditions. So, it is important to assess yield stability in diverse environments. Therefore, stability analysis of six chilli advance breeding lines; NARC Chilli-1, NARC Chilli-2, NARC Chilli-3, NARC Chilli-4, NARC Chilli-5, NARC Chilli-6 was carried out. F_1 hybrid 'Big Daddy' was used as check. Plant material was figured out under Randomised complete Block Design with three replications and four locations; Chakwal, Faisalabad, Islamabad and Swat. Combined analysis of variance showed that mean yield of chilli advance lines at four locations were statistically significant. Genotype x locaton had significant interaction suggesting inconsistent performance of chilli genotypes over environments. The NARC Chilli-2 has regression slope equal to one with relatively low Wricke's Ecovalence, low value of Shukla's Stability Variance, relatively less value of deviation from regression and highest value of coefficient of determination. Results of stability analysis revealed that NARC Chilli-2 was the most stable line with reference to yield and this could be recomended for planting under different type of sites. NARC Chilli-6 and NARC Chilli-4 could be suitable for adequate environmental conditions while NARC Chilli-1, NARC Chilli-3 and NARC Chilli-5 for inadequate environmental conditions. Environment of Chakwal was found most productive and that of Faisalabad was poorest.

Received | August 21, 2020; **Accepted** | March 07, 2021; **Published** | October 31, 2021
***Correspondence** | Hidayatullah, Vegetable Crops Research Crops Research Programme, Horticultural Research Institute, National Agricultural Research Centre Islamabad, Pakistan; **Email:** hidayatu_2003@yahoo.co.uk
Citation | Hidayatullah, S. Mahroof, S. Abid, N. Anjum, N. Habib, A. Saeed and M.A. Farooq. 2022. Stability analysis of advanced chilli lines. *Sarhad Journal of Agriculture,* 38(1): 11-15.
DOI | https://dx.doi.org/10.17582/journal.sja/2022/38.1.11.15
Keywords | Stability measures, Regression coefficient, Chilli genotypes, Adaptability behaviour, Advance breeding lines

Introduction

Chilli (*Capsicum annum L.*) is not only a vegetable but also a spice crop having a considerable economic value in Pakistan and belongs to solanaceae family. Chilli is known as third important crop of solanaceae family after tomato and potato (Dubey *et al.*, 2017). It is vital element in day to day curries, chatnies and pickle. Chilli is immensely profitable crop and pay good returns to growers. Chillies are grown at larger scale in Pakistan, occupying the major zone after onion and potato (Altaf *et al.*, 2019). Chillies are acquired seasonally but consumed right through the year. Chillies production has been mounting since late 1990s. Currently it increased approximately up to 7 million tons per year from 2.5 million tonnes in the last decade. India is the world's leading chillies grower with annual production of

1.1 million tonnes followed by China, Mexico and Pakistan (around 0.2 million tons) (Khokhar, 2013).

In Pakistan, since 2000-01 to 2010-11 chillies crop growing area has been decreased from 174.6 to 171.8 thousand tonnes. Sindh is the largest grower of chilli with respect to area 55.3 thousand hectares and production 122.9 thousand tonnes (GoP, 2013). High yielding varieties and improved production technology must be adopted to get the potential yield.

Chilli, being sensitive to environmental variations exhibits large fluctuations in yield. The comparative feat of genotype for quantifiable features like yield and others which control the yield differ from one site to another. Therefore, to evolve a most promising genotype with significant yield capacity and uniformity, big concern is about the significance of non- fluctuating performance for the genotypes under various ecological conditions (Kumar *et al*., 2019). Phenotypically stable genotypes are of great importance, because environmental condition varies from region to region. Wide adaptation to particular environment and consistent performance of genotypes is one of the main objectives in breeding programme (Spaldon *et al*., 2017). Phenotypic expression of the genotype is variable when grown in different environments. It is observed that genotype x environment (G x E) interaction is widely present and it had a great importance for plant breeders (Cuartero and Cubero, 1982).

The plant breeders have long been aware of the problems of differential response of a genotype when tested under different environments; however, they were unable to quantify the same due to complexities of environments. Breeders used different methodologies to evaluate and address the challenges created by genotype x environment interaction. The predominant surroundings alongside genotype and its interaction are considered the fundamental aspect for evolving the ultimate yield. Expression of quantitative character depends on genotype x environment interaction which is guarded by polygenic system and significantly reshaped through environmental changes. Therefore, concerning to have free and fair projections of different genetic constituents, the undertakings must be repeated at diverse locations (Bhalala and Acharya, 2019). Thus, assessment of varieties by stability parameters over against more than one environments is pre-requisite to recognise the uniform and most promising cultivars (Gurung *et al*., 2012). This multi environmental evaluation of genotypes grants an opportunity to plant breeder to check the adjustability of a genotype to a specific environment and also the steadiness of the genotypes over diverse locations.

Therefore, it becomes essential to search out the germplasm not only having high yield potential but also a stable performance under varying environmental conditions. Hence the present investigation was undertaken to analyse the effect and immensity of genotype-environment correspondence and for identifying and selecting stable genotypes with higher yield.

Materials and Methods

Experiment was conducted at four different locations; Agricultural Research Institute (ARI) Mingora Swat (34.4647°N, 72.1947°E), Ayub Agricultural Research Institute (AARI) Faisalabad (31.4041°N, 73.0487°E), Barani Agricultural Research Institute (BARI) Chakwal (32.9297°N, 72.7223°E) and National Agricultural Research centre (NARC) Islamabad (33.6701°N, 73.1261°E) having different soil type and agro-climatic conditions (Table 1). Plant material including six advanced breeding lines of chillies (NARC Chilli-1, NARC Chilli-2, NARC Chilli-3, NARC Chilli-4, NARC Chilli-5 and NARC Chilli-6) along with a check (Big Dady) was evaluated in multi-environmental trials. At particular sites, the experimental design was randomised complete block with three replications. Seedlings were transplanted during March, 2015 (Faisalabad: 04 March; NARC: 20 March; Chakwal: 26 March; Swat; 30 March) and fruit was harvested sequentially during May-June. The experimental data was analyzed by using different statistical techniques such as combined analysis of variance of chillies yield data over all environments, and stability analysis for genotype-environment data. The stability parameters are helpful in differentiating genotypes by observing their comparative performance in diverse surroundings. The genotype means, variance (S_i^2), coefficient of variation (CV), Wricke's Ecovalence (Wi^2), Shukla's stability variance (σ_i^2), regression slope (b_i), deviation mean square (δ_i^2) and coefficient of determination (R^2) were the different stability parameters studied. Wricke's (1962) ecovalence (W_i^2) stability concept is based on the involvement of all genotype to the GxE interaction summation of squares.

Table 1: *Maximum/ Minimum temperature (°C), Soil Type and Rainfall (mm) during growing season at each location.*

	Islamabad			Chakwal			Faisalabad			Swat		
	Max.	Min.	Raifall	Max.	Min.	Raifall	Max.	Min.	Raifall	Max.	Min.	Raifall
Mar	24	10	90	23	13	15	27	13	21	22	9	72
Apr	30	15	62	30	18	7	34	18	14	26	13	74
May	35	20	39	37	23	1.5	39	23	13	32	18	52
June	39	24	62	38	26	3	41	27	26	35	21	48
Soil type	Loam to Clay loam			Sandy loam			Loam to silt loam			Sandy loam		

Entries with a minimum W_i^2 worth have slighter difference from the overall mean over against environments and are considered to be constant. In the opinion of this parameter a zero ecovalence genotype is considered as steady. Shukla's (1972) stability variance or interaction variance (σ_i^2) is basically a modification of Wricke's ecovalence that one may provide a balanced estimate for G x E varience for all genotypes. A reasonably huge assessment of σ_i^2 will therefore point towards larger insecurity of genotype. i. Coefficient of determination (R_i^2) evaluates the amount of difference in the actual performance of a genotype. With this measure a genotype is considered stable only if value of coefficient of determination (R_i^2) is large. Several of these stability parameters have been used by different researchers such as (Lin *et al*., 1986; Masood *et al*., 2003; Shah *et al*., 2009). Statistical data analysis was carried out using different statistical software namely Minitab v. 16 and GEA-R v. 2.0 (CIMMYT, 2015).

Results and Discussion

Results of combined analysis of varience (Table 2) for yield of chilli genotypes grown at different locations exposed considerable ($p \leq 0.010$) variation between genotypes. Significant GE interaction suggested that the yield performance of chilli genotypes was significantly altered in different location/environments. Highly significant estimates of mean square due to environment for fruit yield indicated that environment behaved differently. The aforementioned were in conventionality with former findings of Kumar *et al*. (2019).

The mean yield (kg/ha) of the six advanced breeding lines of chillies along with 'Big Dady' as check showed significant differences among the genotypes. Check was put in place to be the maximum yielding genotype having the mean yield of 8.317 tons/ha followed by NARC Chilli-6 (5.307 tons/ha), NARC Chilli-4 (4.827 tons/ha), NARC Chilli-1 (4.641 tons/ha), NARC Chilli-2 (4.117 tons/ha), NARC Chilli-3 (3.851 tons/ha) whereas NARC Chilli-5 (3.253 tons/ha) produced the lowest yield over the locations (Table 3).

Table 2: *Combined analysis of variance for yield (kgha^{-1}) of chillies genotypes grown at different locations.*

Source of variation	Degrees of freedom	Sum of square	Mean square	F Statistic	P value
Replication	2	5.25	2.63		
Location	3	596.17	198.72	34.23	0.0000
Treatment	6	196.05	32.68	5.63	0.0001
Location x treatment	18	290.01	16.11	2.78	0.0020
Error	54	313.48	5.81		
Total	83	1400.97			

P≤0.01.

Table 3: *Mean yield of chillies genotypes (tons/ha) grown at four locations of Pakistan.*

Genotypes	Locations				Genotypes means
	NARC, Islamabad	ARI, Swat	AARI, Faisalabad	BARI, Chakwal	
NARC Chilli-1	3.920	3.250	2.243	9.150	4.641
NARC Chilli-2	2.130	3.183	2.333	8.820	4.117
NARC Chilli-3	1.760	4.797	2.883	5.963	3.851
NARC Chilli-4	3.173	3.540	2.567	10.027	4.827
NARC Chilli-5	3.093	3.483	2.297	4.140	3.253
NARC Chilli-6	1.813	3.930	2.970	12.513	5.307
Check	3.760	13.843	2.153	13.510	8.317
Location Means	2.807	5.147	2.492	9.160	4.902

The stability statistics for seven genotypes of chilli grown at four locations of pakistan is presented in Table 4. The stability measures revealed that the regression coefficients ranged from 0.228 (NARC Chilli-5) to 1.686 (Check). The NARC Chilli-2 and

Table 4: *Stability parameters for green fruit yield of seven chilli genotypes grown at four locations of Pakistan.*

Genotypes	Genotypes Means	S_i^2	CV (%)	W_i^2	σ_i^2	b_i	δ_i^2	R^2
NARC Chilli-1	4.64	9.51	66.46	4.81	1.47	0.92	4.45	0.84
NARC Chilli-2	4.12	10.04	76.97	2.24	1.04	1.00	1.99	0.93
NARC Chilli-3	3.85	3.55	48.96	0.42	0.20	0.56	1.72	0.84
NARC Chilli-4	4.83	12.18	72.30	3.50	1.64	1.08	3.25	0.91
NARC Chilli-5	3.25	0.59	23.67	2.48	1.16	0.23	0.30	0.83
NARC Chilli-6	5.31	23.83	91.99	7.54	3.52	1.53	5.45	0.92
Check	8.32	38.76	74.86	48.98	22.86	1.68	35.56	0.69

S_i^2= Genotype variance; Wi^2= Ecovalence; σ^{i2}= Interaction variance; b_i= Regression slope; δ_i^2= Deviation mean square and R^2= Coefficient of determination.

NARC Chilli-4 genotypes has regression slope close to 1 with relatively low Wricke's Ecovalence (W_i^2) (low contribution to the GE interaction), low value of Shukla's Stability Variance (σ_i^2), relatively less value of deviation from regression and highest value of coefficient of determination (R^2=0.93 for NARC Chilli-2 and R^2=0.91 for NARC Chilli-4). NARC Chilli-2 and NARC Chilli-4 genotypes were relatively stable over the four studied locations. These lines could be used under varying type of environments as reported earlier by Tiwari and Lal (2014). According to Eberhart and Russell (1966), the stable genotype point out indicates b_i value equivalent or close to one. Similarly, Petersen (1989) advocated that a stable genotype with regression slope (b) equivalent or extremely close to 1, decreases remaining of the statistics, apart from R^2, which range from 0 to 1. The other stability parameters for NARC Chilli-2 and NARC Chilli-4 such as genotype variance and coefficient of variation were relatively large which indicated that the variation in yield over locations was relatively high. Based on findings of this study, the genotype NARC Chilli-2 and NARC Chilli-4 with a slope of close to unity, a relatively less value of ecovalence, low interaction variance and highest value of R^2 can be considered as stable genotype across different environments. Furthermore, the genotypes possessing 'b' value greater than 1 indicated their adaptability under adequate environmental conditions and the genotypes having 'b' value less than '1' have their adaptability under inadequate environmental conditions (Petersen, 1989). Results of Spaldon *et al*. (2017) and Bhalala and Acharya (2019) for the selection of stable tomato genotypes across environments also confirmed these findings. The genotypes NARC Chilli-6 having regression coefficient (b) greater than unity indicated that this genotype is appropriate for encouraging environments only. On the contrary, the genotypes NARC Chilli-1, NARC Chilli-3 and NARC Chilli-5 had value of regression slope (b) less than 1 could be considered for poor or low yielding environments. This study suggests that maximum statistical measures for yield stability should be adopted to maximize the confidence level before declaring a genotype as stable.

Conclusions and Recommendations

Analysis revealed that the locations had a significant effect on yield performance of chilli genotypes. Based on stability analysis, NARC Chilli-2 could be considered for diverse environments while NARC Chilli-6 and NARC Chilli-4 for high yielding environments. Similarly, NARC Chilli-1, NARC Chilli-3 and NARC Chilli-5 could be recommended for poor yielding environments.

Acknowledgements

Author acknowledges the contribution made by all provincial research organizations (BARI, Chakwal; ARI Swat and AARI Faisalabad).

Novelty Statement

Selection of promising, stable and uniform genotype; NARC Chilli-2 is a novelty as the chilli crop is very sensitive to environmental variations.

Author's Contribution

Hidayatullah: Conceived the idea of the study and finalize the write up.
Sammia Mahroof: Recorded data at NARC.
Saleem Abid: Tested the results with stability analysis procedures.

Naveeda Anjum, Noor Habib and Akhter Saeed: Executed and recorded experiment results at Chakwal, Swat and Faisalabad.

Muhammad Arshad Farooq: Helped in reviewing the related literature.

References

Altaf, M.A., R. Shahid, M.A. Altaf, M.X. Ren, K. Tan, W.Q. Xiang, A. Qadir, A. shakoor and M.M. Altaf. 2019. Effect of NPK, organic manure and their combination on growth, yield and nutrient uptake of chilli (*Capsicum Annum* L.). Hortic. Int. J., 3(5): 217-222.

Bhalala, K.C. and R.R. Acharya. 2019. Stability analysis in tomato (*Solanum lycopersicum* L.). J. Pharmacog. Phytochem., 8(3): 4776-4784.

CIMMYT, 2015. Genotype x environment analysis with R for windows (GEA-R) Version 2.0 statistical software. CIMMYT, Mexico, D.F.

Cuartero, J. and J.I. Cubero. 1982. Genotype x environment in tomato. Theor. Appl. Genet., 61: 273–277. https://doi.org/10.1007/BF00273785

Dubey, A.K., D. Singh, P.S. Rajput, Y. Kumar, A.K. Verma and S.K. Chandraker. 2017. Effect of NPK on plant growth, yield and quality of Capsicum (*Capsicum annum* L.) cv Swarna Under Shade Net Condition. Int. J. Curr. Microbiol. App. Sci., 6(3): 1085-1091. https://doi.org/10.20546/ijcmas.2017.603.125

Eberhart, S.A. and W.A. Russell. 1966. Stability parameters for comparing varieties. Crop Sci., 6: 36-40. https://doi.org/10.2135/cropsci1966.0011183X000600010011x

GoP, 2013. Agricultural Statistics of Pakistan. Ministry of National Food Security and Research (Economic Wing) Islamabad.

Gurung, T., S. Techawongstien and B. Suriharn. 2012. Stability analysis of yield and capsaicinoids content in chili (*Capsicum* spp.) grown across six environments. Euphytica, 187: 11-18. https://doi.org/10.1007/s10681-012-0672-6

Khokhar, K.M., 2013. Present status and prospects of chilies in Pakistan. Horticulture Research Institute, National Agricultural Research Centre, Islamabad (www.agricorner.com)

Kumar, P.A., K.R. Reddy, R. Reddy S.R. Pandravada and P, Saidaiah. 2019. Stability studies among tomato genotypes for yield and processing traits. Int. J. Chem. Stud., 3(3): 17-26.

Lin, C.S., M.R. Binns and L.P. Lefkovitch. 1986. Stability analysis where do we stand? Crop Sci., 26: 894-900. https://doi.org/10.2135/cropsci1986.0011183X002600050012x

Masood, M.A., M.I. Khan and S.Z. Mustafa. 2003. Comparison of different methods of evaluating genotypes in national uniformity wheat yield trials in Pakistan. J. Appl. Sci., 3: 385-390. https://doi.org/10.3923/jas.2003.385.390

Petersen, R.G., 1989. Stability analysis. In: Special topics in biometry. N.A. Khan (Ed.) Pakistan Agricultural Research Council, Islamabad. pp. 60-68.

Shah, S.I.H., M.A. Sahito, S. Tunio and A.J. Pirzado. 2009. Genotype-environment interactions and stability analysis of yield and yield attributes of ten contemporary wheat varieties of Pakistan. Sindh Univ. Res. J., (Sci. Ser.). 41(1): 13-24.

Shukla, G.K., 1972. Some statistical aspects of partitioning genotype-environmental components of variability. Heredity, 29:237-245. https://doi.org/10.1038/hdy.1972.87

Spaldon, S., R.K. Samnotra, R. Dolkar and D.R. Choudhary. 2017. Stability analysis and genotype X Environment interaction of quality traits in tomato (*Solanum lycopersicum* L.). Int. J. Curr. Microbiol. Appl. Sci., 6(2): 1506-1515. https://doi.org/10.20546/ijcmas.2017.602.168

Tiwari, A.K. and L. Gulshan. 2014. Genotype-environment interaction and stability analysis in tomato (*Solanum lycopersicum* L.). Ind. J. Hill Farm., 27(2).

Wricke, G., 1962. Über eine Method zur Erfassung der Ökologischen Streuberite in Feldversuchen. Z. Pflanzenzüchtg. 47: 92-96.