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Stability Analysis of Tomato Advance Lines Across Environments

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Abstract: Four tomato advance breeding lines, NARC Tomato-1, NARC Tomato-2, NARC Tomato-3 and NARC Tomato-4, along with cultivar 'Roma' as check, were evaluated across four diversified locations of Pakistan, i.e., Swat, Chakwal, Faisalabad and Islamabad. The field experiments were laid out in randomized complete block design with three replications. Combined analysis of variance showed highly significant differences for genotypes, environments and genotype by environmental interactions. Stability analysis revealed that NARC Tomato-2 was the most stable line with reference to yield and could be suggested for planting under varying type of environments. NARC Tomato-1 and NARC Tomato-3 could be suitable for high yielding environments, while NARC Tomato-4 for poor yielding environments.

Key words: Stability measures, Regression coefficient, Tomato genotypes.

INTRODUCTION

Plant yield is the function of genotype, environment and their interaction. Significant genotype and environment interaction results in changing behaviour of the genotypes across different environments or variations in the relative ranking of the genotypes (Crossa, 1990). The effect of environmental variation on genotype performance recommends that genotype must be tested in different environments. All the breeding methods had a common objective of developing a variety with consistent performance in different environments. However, genotype by environment interactions pose major problem in developing new cultivars and in choosing suitable cultivars to grow in some specific regions. Generally, genotypes with consistent yield over many environments are preferred to those with high yield in selected environments. Breeders must select cultivars adapted to unpredictable environmental fluctuations, using replicated yield trials over locations and years, which allow the assessment of the genotype by environment interaction and proper germplasm selection (Sharma *et al*., 2016).

Stoffella *et al*. (1984) suggested that the selection of tomato genotypes with stable performance should be considered by breeding programs because differences for yield stability were detected among tomato cultivars in yield trials. Berry *et al*. (1988) re-emphasized the need to grow advanced tomato breeding lines for several seasons when selecting high-yielding stable genotypes. Berry *et al*. (1988) also stated that stability analysis was a useful tool for identifying tomato cultivars adopted by the processing industry in Uruguay and the United States, respectively. Cuartero and Cubero (1982) found that tomato hybrids had higher and more stable yields than their parents in differing environments in Spain. In contrast, Poysa *et al*. (1986) indicated that tomato genotypes with low yields had greater yield stability than genotypes with high but unstable yields in Ontario, Canada.

One of the key steps in determining a stable genotype is to subject the population of potential genotypes to multi locations assessment and establish baseline information on the extent and scope of the genotype by environment interactions. Such breeding goals require fundamental information about the nature and extent of genotype by environment interaction in terms of yield and yield related components.

It was, therefore, felt necessary to study the stability behaviour of newly developed tomato advance lines and their yield performance under

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varying ecological conditions. The breeder then selects those genotypes, which, by some measure, show stability across environments. These stable genotypes provide a stock from, which superior genotypes may be selected (Petersen, 1994).

MATERIALS AND METHODS

Four advanced breeding lines of tomato along with a check/control was evaluated in multi-environmental trials conducted at four locations namely Agriculture Research Institute, Mingora, Swat, Vegetable Research Institute, Ayub Agricultural Research Institute, Faisalabad, Barani Agricultural Research Institute, Chakwal, and Directorate of Vegetable, National Agricultural Research Centre, Islamabad, having different agro-climatic conditions. These advance breeding lines were NARC Tomato-1, NARC Tomato-2, NARC Tomato-3 and NARC Tomato-4, along with cultivar 'Roma', as control. Crop was planted and grown according to the growing periods of respective environments. At each location, the experimental design was randomised complete block (RCB) with three replications. Different statistical techniques were used, such as, combined analysis of variance of tomato yield data over four environments; using the genotype by environment means data for stability analysis. The stability parameters are useful in characterizing genotypes by showing their relative performance in various environments. The genotype mean, coefficient of variation, variance (S_i^2), stability variance (σ_i^2), ecovalence (W_i^2), regression slope (b_i), coefficient of determination (R^2) and deviation mean square (δ_i^2) were obtained as parameters of stability.

Several of these have been summarized and compared by Lin *et al.* (1986). Statistical data were analysed using statistical software Minitab 16 version and Microsoft Excel.

The formulae of stability measures are given below:

1. Genotype Mean

$$\bar{Y}_{i.} = \sum_{j=1}^{q} Y_{ij} / q$$

2. Genotype Variance (s_i^2)

$$s_i^2 = \sum_{j=1}^{q} (Y_{ij} - \bar{Y}_{i.})^2 / q - 1$$

3. Genotype Coefficient of Variation, CV_i

$$CV_i = (\sqrt{s_i^2} / \bar{Y}_{i.}) X 100$$

4. Wricke's (1962), Ecovalence (W_i^2)

$$W_i^2 = \sum_{j=1}^{q} (Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{\bar{Y}})^2$$

5. Shukla's (1972) Stability Variance (σ_i^2), an estimate of the variance of genotype 'i' across environments based on residuals from the two way (GxE) classification. (interaction variance)

$$\sigma_i^2 = [p/(p-1)(q-1)] W_i^2 - SS(GE)$$

$$SS(GE) = \sum_{i=1}^{p} W_i^2 = \sum_{i=1}^{p} \sum_{j=1}^{q} (Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{\bar{Y}})^2$$

6. Eberhart and Russell (1966) (Regression Slope (b_i)

$$b_i = [\sum_{j=1}^{q} (Y_{ij} - \bar{Y}_{i.})(\bar{Y}_{.j} - \bar{\bar{Y}})] / \sum_{j=1}^{q} (\bar{Y}_{.j} - \bar{\bar{Y}})^2$$

7. Deviation Mean Square (δ_i^2)

$$\delta_i^2 = [1/(q-2)][\sum_{j=1}^{q} (Y_{ij} - \bar{Y}_{i.}) - b_i^2 \sum_{j=1}^{q} (\bar{Y}_{.j} - \bar{\bar{Y}})^2]$$

8. Coefficient of Determination (R^2)

$$R_i^2 = [b_i^2 \sum_{j=1}^{q} (\bar{Y}_{.j} - \bar{\bar{Y}})^2] / \sum_{j=1}^{q} (Y_{ij} - \bar{Y}_{i.})^2$$

RESULTS AND DISCUSSION

Results of combined analysis of variance (Table 1) for yield (tons/ha) of tomato genotypes grown at four different locations indicated that F-statistics for location, genotypes and genotypes by location interaction were statistically highly significant at 1% level of significance. Significance of interaction shows that the location/environment has significant effect on yield of tomato genotypes. The overall coefficient of variation (CV) was 13.43% showing consistency of the data over locations.

Table 1: Combined analysis of variance for yield of tomato genotypes grown at four different locations.

Source of variation	Degrees of freedom	Sum of square	Mean square	F-statistic	P-value
Replication	3	18.84	6.28		
Genotypes	4	208.35	52.09	10.63**	0.000
Location	3	2068.81	689.60	140.75**	0.000
Genotypes x Location	12	744.12	62.01	12.66**	0.000
Error	57	279.28	4.90		
Total	79	3319.41			

****Highly significant at 1% level of significance (P ≤ 0.01), CV = 13.43**

The average yield (tons/ha) of the four advanced breeding lines of tomato, along with a control at four different locations (Table 2), showed significant differences among the genotypes and among different locations for a particular genotype. The NARC Tomato-4 was found to be the highest yielding line giving an average yield of 18.67 tons/ha followed by NARC Tomato-3 (17.72), NARC Tomato-1(16.61) and check (15.06), whereas NARC Tomato-2 produces the lowest yield combined over the locations. These results show that NARC Tomato-4 produces the highest yield at three locations; NARC, Islamabad (21.27 tons/ha), AARI, Faisalabad (13.59 tons/ha) and BARI, Chakwal (18.63 tons/ha), whereas at ARI, Swat, NARC Tomato-1 produces the maximum yield (30.05 tons/ha).

Table 2: Mean yield of tomato genotypes (tons/ha) grown at different locations of Pakistan.

Genotypes	**Locations**				**Genotypes means**
	NARC, Islamabad	**ARI, Swat**	**AARI, Faisalabad**	**BARI, Chakwal**	
NARC Tomato-1	17.72	30.05	10.64	8.02	**16.61**
NARC Tomato-2	16.04	23.05	11.40	6.80	**14.32**
NARC Tomato-3	15.03	28.68	9.60	17.60	**17.72**
NARC Tomato-4	21.27	21.20	13.59	18.63	**18.67**
Check	14.12	20.12	12.51	13.51	**15.06**
Location means	**16.83**	**24.62**	**11.55**	**12.91**	**16.48**

The stability statistics (Table 3) shows the regression coefficients ranging from 0.57 (check) to 1.64 (NARC Tomato-1). The genotype NARC Tomato-2 has regression slope close to one with the lowest value of Shukla's stability variance (σ_i^2) (low interaction variance of genotype 'NARC Tomato-2' across locations), smallest value of Wricke's ecovalence (W_i^2) (low contribution to the genotype by location interaction), relatively small value of deviation from regression and high value of coefficient of determination (R^2) demonstrating that NARC Tomato-2 is most stable among all genotypes across four locations studied. This advance breeding line could be used under varying type of environments as reported earlier by Tiwari and Lal (2014). According to Singh *et al.* (2017), a genotype showing b_i value equal to unity is considered to be of average stability and is expected to be adapted to all environments. Similarly, Petersen (1989) supported that a genotype is considered more stable, which has regression slope (b_i) equal to or close to unity and minimizes rest of the stability statistics, except coefficient of determination, which ranges from 0 to 1, and its high value determines the stability of a genotype. The other stability parameters for NARC Tomato-2, such as, genotype variance and coefficient of variation, were relatively large, which indicate that the variation in yield over locations was relatively high. Based on findings of the study the genotype NARC Tomato-2 with a slope close to one, low interaction variance, a relatively less value of covalence, and high value of coefficient of determination can be considered a stable genotype to all environments. Furthermore, the genotypes possessing regression coefficient value greater than one show adaptability in high-yielding or good environments and the genotypes having regression coefficient value less than one have adaptability for low-yielding or poor environments (Petersen, 1989). The NARC Tomato-1 and NARC Tomato-3 genotypes have a high regression coefficient (b_i) than unity which shows that these genotypes are suitable for high yielding or good environments only. On the other hand, the NARC Tomato-4 genotype having coefficient of regression less than one is considered suitable for poor or low yielding environments. This situation confirms that the maximum stability measures for yield stability must be taken to achieve the highest degree of confidence prior to a final decision on genotype releases, which is the ultimate target of all crop breeding programmes.

Table 3: Stability statistics for five tomato genotypes grown at four locations of Pakistan.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Genotypes	**Genotypes Means**	**s_i^2**	**CV (%)**	**W_i^2**	**s_i^2**	**b_i**	**d_i^2**	**R^2**
NARC Tomato-1	16.61	97.13	59.35	24.75	10.25	1.64	12.32	0.96
NARC Tomato-2	14.32	48.07	48.41	2.27	1.06	1.09	21.00	0.85
NARC Tomato-3	17.72	64.42	45.28	30.87	14.41	1.24	33.08	0.83
NARC Tomato-4	18.67	13.00	19.31	40.04	18.69	0.45	17.87	0.54
Check	15.06	11.78	22.78	18.90	8.82	0.57	1.78	0.95

CONCLUSION

NARC Tomato-2 was found to be the most stable line with reference to yield and may be recommended for a wide range of environments. NARC Tomato-1 and NARC Tomato-3 were identified suitable for high yielding environments, while NARC Tomato-4 was suitable for low yielding environments.

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