Veg. Sci. 37(2) : 141-145 (2010)

STABILITY ANALYSIS FOR FRUIT YIELD AND ATTRIBUTING TRAITS IN CHILLI

R Venugopalan and K Madhavi Reddy

Indian Institute of Horticultural Research, Bangalore- 560 089

Summary

An attempt has been made in this communication to elucidate the statistical considerations in different approaches used for developing stability models in vegetable crops. In particular, using three years (2004-06) yield and yield related biometrical characters data on 13 varieties of chilli evaluated in randomized block design with three replications at the experimental plot of Indian Institute of Horticultural Research, Bangalore, efforts have been made to develop suitable stability models with a view to identify stable varieties suitable for commercial exploitation in wide range of environment. Stability models (with R^2 as 75.4 to 97.5 %) developed individually for yield and yield attributing biometrical characters indicated that Arka Lohit (for red fruit yield (95.9 /ha (q)) and dry fruit yield (25.9 /ha(q)) followed by BC 25 were stable, as they possesses least ecovalence values as compared to others. Results also indicated that KA-2 and PANT-5 were identified as lines suitable for favourable environment and LCA 206 (with yield potential of 78.17/ha (q) was classified as an above average varieties which will respond well to a poor environment.

सारांश

सब्जियों में सांख्यिकीय स्थायित्व मॉडल को विकसित करने हेतु विभिन्न विधियों का मूल्यांकन किया गया। विशेषतः मिर्च के 13 प्रजातियों का तीन वर्षों (2004–06) के उपज व उपज से संबंधित गुणों के आँकड़ों का मूल्यांकन खण्ड संरचना का अपनाकर तीन खण्डों में किया गया। उपर्युक्त स्थायी मॉडल को विकसित करने के लिए प्रयास भारतीय बागवानी अनुसंधान संस्थान, बैंग्लौर में इस उद्देश्य से किया गया कि उपयुक्त प्रजाति का व्यावसायिक दृष्टि से उपयेाग बृहद वातावरणीय क्षेत्र में किया जा सकें। स्थायित्व मॉडल (आर 2 75.4 से 97.5%) व्यक्तिगत रूप से उपज व उपज से सम्बधित गुणों से स्पष्ट हुआ कि अकी लोहित (लाल फली उपज (95.9 प्रतिशत) तथा शुष्क फली उपज (25.9 कु./हे.) व इसके बाद बी.सी. 25 स्थायी पायी गयी। जैसा कि इनमें सबसे कम मूल्य अन्य की तुलना में पाया गया। परिणाम से यह भी संकेत मिलता है कि के.ए.–2 तथा पंत–5 प्रजाति उपयुक्त वातावरण स्थायी हैं व एल.सी. एवं 206 (उपज क्षमता 78.17 कु./हे.) प्रजाति औसत से अधिक कर ही जो खराब वातावरण में भी उपयुक्त है।

Introduction

A large number of articles appeared in research journals dealing with stability analysis in vegetable crops, is a testimony to the importance of such studies (c.c for e.g., Arya and Yadhav, 2009; Kalloo, 1998; and Singh *et al.,* 2009). Inferences derived from such studies form the basis for the success of any crop improvement program, which is mainly based on the proper identification of superior varieties for mass propagation and commercial exploitation. The selected varieties should not only be stable but also adaptable over varying environments. Genotypes expressing constant yield over the years in a given environment are termed as stable genotypes and those having constant yield averaged over years across different environments are considered to be widely adaptable. Any breeding efforts to evolve high yielding strains will go a long way in identifying a best variety for further breeding programs, and also for taking care of a situation wherein yield thresholds have been attained.

However, in any crop improvement research, the relative performance of crop varieties is generally different in different environments. This is due to the fact that the performance of a particular variety is the result of its genetic constitution and the environment in which it has been grown. More specifically, a particular variety may not exhibit the same phenotypic performance under different environments or different varieties may respond differently to a specific environment. Thus the plant breeder has to account for an element of specific adaptability with respect to each genotype in its revealed characteristics. This so-called specific adaptability is caused by genotype – environment (GE) interaction.

Among the different approaches, the widely followed by the plant breeders (Arya and Yadhav, 2009; Fennel and Salter, 1977; Kalloo, 1998; Prasad, 1999 and Singh *et al.,* 2009) is the the Eberhart and Russell (ER) model (Eberhart and Russell, 1966). However, this approach employs statistically invalid regression (Prabhakaran and Jain, 1992) thus resulting in improper grouping of varieties and subsequently drawing erroneous conclusion about the stability and adaptability of varieties. Usually stability analysis helps the breeder to identify three groups of varieties for direct use in appropriate environments. However, a theoretically ideal variety is one, which possesses a relatively higher yield and stable performance in the low-yielding environments as well as capacity to respond to favourable environments. Keeping the importance attached to such studies, it is highly essential for the researchers to employ a suitable approach, thus preventing any erroneous conclusions, also to draw meaningful conclusions about the extent of GE interaction so as to facilitate in selecting appropriate genotypes/varieties for further use in hybridization program.

Materials and Methods

Thirteen chilli genotypes (namely SKAUP-C-101, KCS 2013, BC 40-2, BC 25, F112-5-83, LCA 206, JCA 283, Arka Lohit, KA-2, Pant-5, Pant-4,LCA 333 and Ajeet-6) were evaluated at the experimental farem of Indian Institute of Horticultural Research, Bangalore during for three years 2004 to 06 (Kharif) were utilized for developing stability models so as to identify stable varieties suitable for wide range of invironment for cultivation. Here, environment refers to years and not to locations. Information pertaining to the characters namely, Days to 50% flowering, Fresh to dry recovery, fruit length (cm), fruit breadth (cm), plant height (cm) and plant spread (cm) along with red fruit Yield/ha (q), dry fruit yield /ha (q), were utilized for developing stability models.

Comparison of statistical methods: Classical regression technique is the widely used statistical tool to perform stability analysis in vegetable crops research. Here, the dependent variable (phenotypic value such as yield/plant) is regressed over the independent variables (genotypic and environmental factor) to perform the regression. The commonly used model as purpose by Eberhart and Russell (1966), Freeman and Perkins (1971) and Venugopalan and Gowda (2005) were followed for stability analysis.

Results and Discussion

As a first step, three years data on fruit yield and attributing traits were subjected to a detailed analysis of variance to test about the significance of genotypes over environment. Initial results indicate about the differential behavior of all the 13 varieties across three years which allowed to proceed for stability analysis.

Results of stability analysis presented in Table 1 confirmed the presence of G X E interaction as the mean sums of squares for all the characters across the genotypes were significantly differing from each other ($p < 0.05$). Furthermore, the significance of GE mean square when tested against the average errors confirms the presence of GE interaction in data set. This shows that the genotypes had divergent linear response to environmental changes. The significance due to pooled deviation when tested against the average error, ensure our conclusion that overwhelming portion of the GE interaction is of linear type.

Further, testing the individual deviations against the average error helps us to identify the genotypes for which the interactions are entirely linear, enabling us to choose a genotype for specific adaptation. Also, by making use of the test statistic described earlier, we have tested for deviation of regression coefficient from unity for all the 13 chilli varieties. Due to the similarity in the methods of ER and PJ, the results of latter method are not presented and discussed here. The three measures of stability values, *viz.,* bi, s^2d_i and W_i are also worked out and are presented in Table 3. A measure based upon W_i and S^2d_i will further help us in grouping. Based on these measures, varieties are grouped into three groups and the results are presented separately for ER and FP methods in Table 3. Further, as an in depth study of the results achieved under ER and FP methods pertaining to target group of the breeders, *viz.,* ideal genotype group, based on their W_i values genotypes are ranked and are presented in Table 5. Perusal of the results presented in Table 3 to Table 5 separately for Eberhart - Russell method and the Freeman-Perkins approach brings out the following salient results:

Fruit Yield/ha (q) : In case of red fruit yield /ha (q), four out of 13 varieties (BC 40-2, ARKA LOHIT, LCA 333, AJEET-6) were identified as ideal, suitable for wide range of environment under ER model; where as seven (*viz.,* SKAUP-C-101, KCS 2013, BC 25, JCA 283, ARKA LOHIT, LCA 333, AJEET-6) were grouped into the ideal category through the FP model. However, between these approaches three lines, SKAUP-C-101, KCS 2013 and JCA 283 classified as ideal lines suitable for wide range of cultivation under FP procedure was misclassified into other two groups in the ER approach.

Table 1. Analysis of variance for different characters under three different procedures

Source / Character	Red Frt. Yield/ha (q)	Dry Frt. Yield/ha (q)	Days to 50% Flowering	Fresh: Dry recovery (%)	Frt. Length (cm)	Frt. width (cm)	Pl. height (cm)	Pl. spread (cm)
	1	2	3	4	5	6	7	8
			Eberhart-Russell (ER) Method					
Genotype	605.43	65.57	13.77	25.67	3.41	0.06	115.06	51.12
V x Env (Linear)	412.48	34.53	8.5	9.83	1.67	0.04	53.29	37.30
Pooled Deviations	439.10	12.66	5.63	16.56	1.89	0.04	22.05	25.70
Average Error	81.20	7.86	1.48	1.27	0.09	0.002	13.511	8.30
			Freeman-Perkins (FP) Method					
Genotypes	593.10	78.82	14.70	26.86	3.25	0.06	118.43	47.79
Environments	12134.55	508.91	71.68	80.42	23.81	0.07	2165.15	3385.27
Combined reg.	24138.93	1009.85	98.74	160.85	47.60	0.14	4282.87	6720.72
Residual	130.17	7.97	44.61	0.004	0.065	0.008	47.43	49.81
Hetero of reg.	406.87	45.18	6.72	9.96	1.75	0.04	50.54	48.34
Residual	547.40	17.24	11.82	18.73	2.13	0.04	30.29	29.82
Average Error	126.92	15.54	3.12	3.07	0.215	0.002	19.71	12.14

Table 2. Stability parameters of six quantitative traits under Freeman-Perkins model

Name of the lines	Red fruit Yield/ha (q)				Dry fruit Yield/ha (q)				Days to 50% Flowering			
	Xi	bi	s2di	wi	Xi	bi	S2di	wi	Xi	bi	S2di	wi
SKAUP-C-101	53.13	.62	112.0	302.3	10.42	0.77	16.57	31.47	27.08	.67	86.14	57.9
KCS 2013	54.6	1.09	27.53	247.41	12.27	1.21	6.1	15.37	25.8	1.88	17.73	20.85
BC 40-2	57.75	1.15	743.62	1091.5	10.37	0.81	4.8	33.99	31.7	0.68	2.4	33.23
BC 25	50.53	1.12	160.57	201.98	11.75	1.48	13.6	8.2	30.17	0.62	0.39	0.46
F112-5-83	58.4	1.58	975.43	1822.7	10.95	1.25	0.8	24.32	30.5	0.74	22.06	47.26
LCA 206	78.17	0.46	245.87	843.7	15.14	0.5	14.86	23.03	32.75	0.63	1.69	0.5
JCA 283	64.29	0.04	87.79	2045.3	17.6	0.97	1.85	289.42	30.5	0.11	12.25	9.99
Arka Lohit	94.12	0.87	29.31	136.4	25.8	0.76	3.7	15.3	34	0.06	7.4	8.49
KA-2	81.51	1.84	389.4	1493.56	22.45	2.78	0.35	178.9	30.5	2.09	7.69	21.4
Pant-5	65.25	1.61	63.14	593.6	12.49	1.58	15.29	14.5	31.5	1.4	1.32	4.3
Pant-4	53.45	1.04	2441.4	2258.05	11.02	1.36	43.78	51.2	32.17	0.56	0.62	12.5
LCA 333	56.38	1.02	81.67	310.66	18.8	1.85	13.06	53.9	31.83	1.22	2.55	3.2
Ajeet-6	45.10	1.04	3.48	68.18	10.01	1.97	10.49	9.5	32.0	1.2	1.8	2.6

Name of the lines	Fresh: Dry recovery (%)				Fruit Length (cm)				Plant Height (cm)			
	Xi	bi	S2di	wi	Xi	bi	S2di	wi	Xi	bi	S2di	wi
SKAUP-C-101	19.65	1.53	72.0	76.5	7.5	1.14	1.61	1.76	75.67	0.77	52.71	50.59
KCS 2013	22.52	0.24	14.6	25.04	7.2	2.0	1.32	5.7	71.3	0.85	3.23	9.04
BC 40-2	19.4	1.2	4.3	7.2	5.1	0.42	3.4	5.04	77.05	1.2	132.35	148.5
BC 25	22.95	0.04	1.63	14.73	6.98	1.3	2.14	3.07	67.7	1.57	30.3	209.97
F112-5-83	21.6	1.66	18.9	24.9	7.1	0.89	0.24	0.38	70.1	0.67	19.71	24.4
LCA 206	20.3	0.88	5.8	48.8	7.1	0.6	0.18	0.57	71.7	0.64	14.98	87.2
JCA 283	25.6	2.5	29.03	52.4	7.1	0.8	3.42	4.1	67.8	0.58	10.23	65.5
Arka Lohit	28.4	2.14	1.1	15.01	7.5	0.81	0.54	0.97	80.3	0.84	6.93	12.1
KA-2	28.06	1.06	0.82	2.2	6.14	0.62	0.45	10.5	57.17	0.70	8.74	43.0
Pant-5	20.1	0.99	2.5	0.7	7.1	1.53	1.6	2.9	76.8	1.28	9.6	85.9
Pant-4	24.2	2.51	30.4	53.6	9.4	1.83	0.6	3.95	76.7	1.43	16.3	130.9
LCA 333	24.5	0.98	1.72	1.6	7.7	0.93	0.07	0.21	75.42	0.53	19.7	59.7
Ajeet-6	23.05	0.57	15.5	21.72	8.7	0.89	7.78	7.62	65.0	0.60	1.5	43.24

Thus the extent of loss on information about ideal lines is about 50% due to the use of former approach. Looking into the values of mean performance (X_i) of these ideal lines (Table 3), Arka Lohit performed better (94.12/ ha (q)), across the years, than all the other lines. Ecovalence values (W_i) worked out (Table 5) for the ideal lines showed that Arka Lohit followed by BC 25 were stable for wide range of cultivation for red fruit yield/ha (q), as they possesses least ecovalence values as compared to other lines. Further, LCA 206 (with yield potential of 78.17/ha (q) is classified as an above average genotype which will respond well to a poor environment. Two varieties, *viz.*, KA-2 and PANT-5 were identified by FP model, as lines suitable for favourable environment.

Similarly for the other characters, Perusal of Table 3

Table 3. Grouping of varieties based on the results of Stability analysis (under ER and FP model)

Sl no	Character	Ideal genotype[1] $b_i = 1$ and $S^2d_i = 0$	Above Average Genotype[2] $b_i < 1$ and $S^2d_i = 0$	Below Average Genotype[3] $b_i > 1$ and $S^2d_i = 0$	Extent of misclassification (%) of ideal lines due to ER model.
1.	Red fruit ER MOD Yield/ha (q) FP MOD	BC 40-2, ARKA LOHIT,LCA 333, AJEET-6 SKAUP-C-101,KCS 2013,BC 25,JCA 283,ARKA LOHIT,LCA 333,AJEET-6	SKAUP-C-101,JCA 283 LCA 206	KA-2,PANT-5 KA-2,PANT-5	50 %
2.	Dry fruit ER-MOD yield /ha (q) FP MOD	SKAUP-C-101,KCS 2013,BC 40-2,,F112-5-83,KA-2,PANT-5,PANT-4,LCA 333,AJEET-6 SKAUP-C-101,KCS 2013,BC 40-2, BC 25,F112-5-83,LCA 206,JCA 283,ARKA LOHIT,AJEET-6	LCA 206,JCA 283,ARKA LOHIT -	BC 25 KA-2,PANT-5,PANT-4,LCA 333	44%
3.	Days ER MOD to 50% flowering FP MOD	BC 25,F112-5-83,LCA 206,LCA 206,JCA 283,ARKA LOHIT,KA-2,PANT-5,PANT-4,LCA 333,AJEET-6 BC 40-2,BC 25,LCA 206,ARKA LOHIT,PANT-5,PANT-4,LCA 333,AJEET-6	BC 40-2 -	KCS 2013 -	12.5%
4.	Fresh to ER MOD dry recovery (%) ER model FP MOD	BC 40-2,KA-2,PANT-5,LCA 333 BC 40-2,BC 25,LCA 206,KA-2,PANT-5,LCA 333	BC 25 KCS 2013,AJEET-6	- SKAUP-C-101,JCA 283,ARKA LOHIT	33%
5.	Fruit ER MOD length (cm) FP MOD	LCA 333 F112-5-83,LCA 206,KA-2,LCA 333	LCA 206 -	- -	75%
6.	Fruit ER MOD breadth (cm) FP MOD	BC 40-2,PANT-4,LCA 333 PANT-4	- -	SKAUP-C-101 -	NIL
7.	Plant ER MOD height (cm) FP MOD	SKAUP-C-101,KCS 2013,F112-5-83,LCA 206,PANT-5,LCA 333 F112-5-83,LCA 206,JCA 283,KA-2,LCA 333,AJEET-6	ARKA LOHIT,KA-2,AJEET-6 -	BC 25,PANT-4 -	50%
8.	Plant ER MOD spread (cm) FP MOD	F112-5-83,PANT-5,LCA 333 KCS 2013,KA-2,PANT-4	SKAUP-C-101,LCA 206,ARKA LOHIT,AJEET-6 SKAUP-C-101,F112-5-83,LCA 206,JCA 283,ARKA LOHIT,LCA 333,AJEET-6	KCS 2013,PANT-4 BC 40-2,PANT-5	100%

1 Suitable for wide range of environment 2 Suitable for poor environment 3 Suitable for favorable environment

to Table 5 revealed about marked difference among the number of varieties grouped separately under two methods. Results indicated clearly about the change in cluster membership while adopting Freeman-Perkins model. The information loss about ideal lines suitable for wide range on environment was as high as 100%, in the case of plant spread, 50 % in the case of red fruit yield and 44% in the case of dry fruit yield.

To summarize, stability models (with R^2 = 75.4 to 97.5 %) developed for yield and yield attributing biometrical characters of 13 varieties of chilli evaluated during the period 2004-06 (Kharif) indicated that Arka Lohit followed by BC 25 were stable for wide range of cultivation for red fruit yield/ha (q), as they possesses least ecovalence values as compared to other varieties. Results further indicated Arka Lohit was stable for wide range of cultivation for red fruit yield (95.9 /ha (q)) and dry fruit yield (25.9 /ha(q)). KA-2 and PANT-5 were identified as lines suitable for favourable environment and LCA 206 (with yield potential of 78.17/ha (q) was classified as an above average genotype which will respond well to a poor environment. The goodness of fit of these models were worked out be in the range of 75%-97.5%. Thus the results obtained fortify the efficacy of the Freeman and Perkins approach in proper grouping of the lines based on their suitability to the characteristics of the environment.

The message arising out from this present study is that breeders may exploit the use of Freeman-Perkins approach for performing stability research while conducting multi-location/year trails. A window based statistical package was also developed to carryout stability analysis using three different approaches and

Table 5. Ranking among ideal Chilli lines under Eberhart-Russell (ER) and Freeman-Perkins (FP) models based on measure of ecovalence

Name of the character	Based on Eberhart-Russell (ER) Procedure		Based on Freeman-Perkins (FP) Procedure	
	Ideal Genotype	Ranked W_i values	Ideal Genotype	Ranked W_i values
1. Red fruit Yield/ha (q)	LCA 333	269.108	A. LOHIT	136.372
	BC 40-2	273.873	BC 25	201.977
	BC 25	289.552		
2. Dry fruit Yield/ha (q)	AJEET-6	8.063	BC 25	8.186
	LCA 333	10.742	AJEET-6	9.520
	BC 40-2	11.473	A. LOHIT	14.490
3. Days to 50% flowering	BC 25	0.637	BC 25	0.463
	LCA 206	0.637	LCA 206	0.498
	AJEET-6	1.780	AJEET-6	2.257
4. Fresh : dry recovery (%)	PANT-5	0.437	PANT-5	0.701
	LCA 333	1.024	LCA 333	1.595
	KA-2	1.626	KA-2	2.196
5. Fruit length (cm)	LCA 333	0.348	LCA 333	0.209
			F112-5-83	0.381
			LCA 206	0.567
6. Fruit breadth (cm)	BC 40-2	0.003	PANT-4	0.007
	PANT-4	0.006		
	LCA 333	0.009		
7. Plant height (cm)	F112-5-83	24.367	F112-5-83	5.104
	KA-2	43.007	KCS 2013	27.23
	AJEET-6	43.239	SKAUP-C-101	29.152
8. Plant spread (cm)	PANT-5	8.801	KA-2	61.976
	LCA 333	11.836	KCS 2013	36.093
	F112-5-83	23.039	PANT-4	108.435

to compute different measures of stability. Thus, this study will be useful in taking appropriate inference about a group of stable varieties which are less sensitive to the temporal environmental changes that may take place.

References

Arya RK and Yadav HP (2009). Stability of grain yield and its contributing traits in white and grain hybrids of pearl millet (*Pennisetum glaucum*). Indian J. Agril.Sci. 79 (11): 941-44.

Eberhart AS and Russell WA (1966). Stability parameters for comparing varieties. Crop Sci. 6**:** 36-40.

Fennel JFM and Salter PJ (1977). Genotypic and environment variation in Autumn-sown Onions. Theor. Appl. Genet. 51:21-28.

Freeman HG and Perkins JM (1971). Environmental and genotype-environmental components of variability. VIII. Relations between genotypes grown in different environments and measures of these environments. Heredity. 27: 15-23.

Kalloo G, Chaurasia, SNS and Singh M (1998). Stability analysis in Tomato. Veg.Sci. 25(1): 81-84.

Prabhakaran TV and Jain JP (1992). Statistical techniques for studying Genotype-Environment interactions. SAP Pvt.Ltd. New Delhi. PP 320.

Prasad VSRK, Singh DP, Pal AB, Rai Mathura and Yadav IS (1999). Assessment of adaptability in parwal (*Trichosantheses dioica Roxb*.) Indian J. Hort. 56(1):52-61.

Singh BS, Sharma MM and Singh AK (2009). Stability analysis for grain yield and yield contributing traits in maize (*Zea mays*) single cross hybrids under mid hills. Indian J. of Agril. Sci. 79 (11): 890-96.

Wricke G (1962). Uber eine Methods Sur Erafassung der okologischen streubreite in Foldversuchan. Z. Pflanzonzuchig. 47:92-96

Venugopalan R and Veere Gowda R (2005). Stability Analysis In Onion: A Statistical Look. J. Indian Soc. Coastal agric. Res., 23(2): 123-29.