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Statistical models for stability analysis in watermelon

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ABSTRACT

Fourteen promising F_1 hybrids of watermelon namely IIHR-188 X IIHR-118, IIHR 114 X IIHR 118 , IIHR 119 X IIHR-20-1, Arka Manik X IIHR 46, IIHR 43 X IIHR 46, Arka Manik X IIHR-188, Arka Jyothi, NS-295, Kushboo, Madhubala, Apoorva, CWH-7 and Riya were evaluated in experimental plots of Division of Vegetable Crops, Indian Institute of Horticultural Research, Bangalore during 2002-04. Information about biometrical characters such as fruit length (cm), fruit girth (cm), days to first male flower opening & female flower opening, rind thickness(cm) and TSS (%) along with yield (t ha^{-1}), were used to develop stability models to identify stable hybrid(s) for a wide range for cultivation. Stability models thus developed indicated that two hybrids, viz., Arka Jyothi (with yield potential of 75.91 t ha^{-1}) across the years and NS-295 (64.25 t ha^{-1}) were stable for a wide range for cultivation. Statistical measures of stability, viz., regression coefficient, deviation from regression co-efficient and ecovalence measures, were worked out and utilized for grouping of hybrids into different categories based on their cumulative performance over the years.

Key words: Ecovalence measure, GE interaction, stability models, watermelon

INTRODUCTION

In any crop improvement research, plant breeders before recommending release of a particular variety/hybrid for commercial exploitation in farmer's field, ensure the stability of varieties, by testing it across different environments/periods. In such studies, the breeders' main interest will be to estimate the average response of the varieties and also to test the consistency of the yield response from region to region/environment to environment. The presence or absence of the so-called Genotype x Environment (GE) interaction, coupled with high yield, will largely dictate the good performance of the genotypes. However, in practice, genotypes responsible for showing higher yield are less stable and vice versa. The presence of such a GE interaction also alters the relative ranking of different varieties in addition to reducing the correlation between phenotype and genotype, thus making it difficult for a breeder to judge the true genetic potential of variety. Hence, the main aim was to strike a balance between these two extremes by evolving appropriate statistical methods to reduce the component of GE interaction for identifying stable genotypes that interact less with the environment.

MATERIAL AND METHODS

Fourteen promising F_1 hybrids of watermelon namely, IIHR-188 X IIHR-118, IIHR 114 X IIHR 118 , IIHR 119 X IIHR-20-1, Arka Manik X IIHR 46, IIHR 43 X IIHR 46, Arka Manik X IIHR-188, Arka Jyothi, NS-295, Kushboo, Madhubala, Apoorva, CWH-7 and Riya evaluated in the experimental plots of Division of Vegetable Crops, Indian Institute of Horticultural Research, Bangalore during 2002-04, were utilized to develop stability models with a view to identify best variety(s) for commercial exploitation based on Yield (t ha^{-1}), fruit length (cm), fruit girth (cm), days to first male flower opening & female flower opening, Rind thickness(cm) and TSS (%).

Two different approaches based on Eberhart and Russell (ER) model (Eberhart and Russell, (1966); Bhargava *et al.*, 2008) and Freeman and Perkins (FP) model (Dehghani *et al.*, 2008, Freeman and Perkins, 1973) were utilized for carrying out stability analysis research. The details of these methods are well elucidated in Prabhakaran and Jain (1992) and more recently from application of point of view by Venugopalan and Gowda (2005).

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Measures of stability

Different measures of stability viz., mean performance (X_i), regression coefficient (b_i), deviation from regression coefficient (S^2d_i) and Wricke's ecovalence (W_i) measures (Wricke ,1962) were computed using standard formulae, as given below :

(i) Regression coefficient (b_i):

$$b_i = \Sigma (Y_{ij}-\bar{Y}_{i}.)(\bar{Y}_{.j}-Y..) / S (\bar{Y}_{.j}-\bar{Y}..)^2$$

(ii) Deviation from regression (S^2d_i):

$$S^2d_i = [[\Sigma (Y_{ij}-\bar{Y}_{i}.)^2 - bi^2 \Sigma (\bar{Y}_{.j}-\bar{Y}..)^2] / (s-2)] - S^2_e$$

(iii) Wricke's ecovalence (Wi):

$$W_i = \Sigma (Y_{ij}-\bar{Y}_{i.}-\bar{Y}_{.j}-\bar{Y}..)^2$$

Based on the these measures, hybrids were classified into any one of the following three groups.

Group I: Ideal genotype (suitable for wide range of environment) b_i=1 and S^2d_i =0

Group II: Average stability genotype (Suitable for poor environment) b_i<1 and S^2d_i =0

Group III: Above average stability (suitable for favorable environment) b_i>1 and S^2d_i =0.

In general, a hybrid showing high yield potential under favorable environment and having great phenotypic stability is considered to be stable. Moreover, the lower the value of W_i smaller will be the fluctuations from the predictable response in different environments. Accordingly, as an index of ranking in their order of stability/adaptability characteristics, the genotype with least ecovoalence is considered to be the most stable.

RESULTS AND DISCUSSION

Results of analysis of variance indicated for a differential behavior of all the 14 hybrids across three years (2002-04). Results of stability analysis presented in Table 1 confirmed the presence of (Genotype X Environment) G X E interaction as the mean sums of squares for all the characters across the genotypes were significantly differing from each other ($p<0.05$). This shows that the hybrids had divergent linear response to environmental changes. Four measures of stability values, viz., X_i, b_i, S^2d_i and W_i were also worked out and are presented in Table 2. Based on these measures, genotypes were grouped into three groups (specific to their adaptability to a given environment) and the results are presented separately for ER and FP methods in Table 4. Further, as an in depth study of the results achieved under ER and FP methods pertaining to target group of the breeders, viz., ideal hybrids group, based on their W_i values, 14 hybrids were ranked and are presented in Table 4. Perusal of the results presented in Table 2 to Table 4 brings out the following salient findings:

Yield (t ha^{-1}) : Under the Freeman-Perkins model three F_1 hybrids (Arka Jyothi (c), Riya, and NS 295) were identified as ideal, suitable for wide range of cultivation. Looking into the values of mean performance (Xi) of these ideal lines (Table 2), Arka Jyothi performed better (75.91 t ha^{-1}), across the years, followed by NS-295 (64.25 t ha^{-1}), than all the other lines. Accordingly, ecovalence values (W_i) worked out (Table 4) for the ideal lines showed that Arka Jyothi followed by NS 295 were stable for wide range of cultivation for yield t/ha, as they possesses least ecovalence values as compared to other lines. Further, IIHR-178 x Arka Manik (with yield potential of 51.93 t ha^{-1}) is classified as an above

Table 1. Sability analysis for different characters in Watermelon (Mean sum of squares)

Source / Character	Yield (t/ha)	Fruit length (cm)	Fruit girth (cm)	Days to first male flower opening	Days to first opening female flower	Rind thickness (cm)
Eberhart-Russell (ER) Method						
Genotype	190.15	29.66	29.14	2.337	2.67	0.04
V x Env (Linear)	85.29	16.61	0.311	1.073	1.82	0.08
Pooled Deviations	45.46	2.54	1.70	0.914	0.71	0.06
Average Error	0.52	1.16	0.23	0.239	0.34	0.003
Freeman-Perkins (FP) Method						
Genotypes	191.63	28.98	29.81	2.442	2.44	0.045
Environments	329.09	38.65	0.14	2.851	4.17	0.007
Combined reg.	653.52	73.61	0.03	5.707	8.34	0.009
Residual	4.65	3.69	0.24	0.001	0.001	0.004
Hetero of reg.	85.81	17.29	0.50	1.142	2.33	0.070
Residual	55.59	4.08	1.10	0.826	0.49	0.083
Average Error	0.77	2.20	0.27	0.345	0.45	0.005

Table 2. Stability parameters of six quantitative traits for 14 watermelon lines under Freeman-Perkins model

Name of the hybrid	Yield (t/ha)				Fruit length (cm)				Fruit girth (cm)			
	$\bar{X}_i$	b_i	S^2d_i	W_i	$\bar{X}_i$	b_i	S^2d_i	W_i	$\bar{X}_i$	b_i	S^2d_i	W_i
IIHR-178 x Arka Manik	51.93	0.63	3.12	7.93	22.58	1.46	-2.19	2.5	21.00	-0.98	1.8	2.06
IIHR-114 x IIHR-118	63.41	1.56	15.77	27.59	21.75	-0.62	-1.71	16.81	18.83	-0.45	0.71	0.82
IIHR-119 x IIHR-20-1	51.91	2.08	67.65	115.55	27	2.08	-1.16	12.16	21.88	0.05	-0.23	0.0
IIHR-118 x IIHR-20-1	62.16	2.58	129.72	237.81	20.92	-0.5	-2.08	12.91	18.83	-0.71	2.23	2.31
Arka Manik x IIHR-46	61.2	2.49	23.06	136.9	21.25	-0.3	1.68	7.69	19.98	1.75	-0.26	0.9
IIHR-43 x IIHR-46	52.43	-1.47	134.09	427.74	22.58	-0.18	-2.14	7.79	17.9	-0.19	-0.24	0.1
Arka Manik X IIHR-188	52.58	3.0	36.44	221.7	24.25	2.6	-2.18	20.44	21.08	-0.35	-0.26	0.06
Arka Jyothi (C)	75.91	0.07	2.0	44.83	26.58	0.28	-2.18	2.62	19.46	-1.1	-0.23	0.53
NS-295 (C)	64.25	0.88	7.44	14.22	28.63	3.43	-0.77	47.41	21.41	0.7	0.11	0.36
Kushboo	58.08	-0.35	13.74	104.54	22.5	-0.54	-1.07	14.04	14.16	-0.53	-0.06	0.22
Madhubala	56.25	0.81	97.64	111.69	27.72	3.87	-2.12	61.62	18.75	0.0	-0.27	0.01
Apoorva	51.01	1.54	124.77	127.25	25.97	1.5	-1.86	3.77	28.41	-1.15	-0.13	0.52
CWH-7	45.76	1.04	51.94	61.56	19.67	-0.55	45.9	55.08	17.66	0.62	0.15	0.69
Riya	48.08	-1.00	-0.76	188.85	18.92	-0.5	-2.08	12.91	18.41	3.56	7.39	12.09
Name of the hybrid	**Days to first male flower opening**				**Days to first female flower opening**				**Rind thickness(cm)**			
	X_i	b_i	S^2d_i	W_i	X_i	b_i	S^2d_i	W_i	X_i	b_i	S^2d_i	W_i
IIHR-188 x Arka Manik	32.42	1.35	0.95	1.57	36.6	0.1	-0.39	0.57	1.26	1.81	0.14	0.14
IIHR-114 x IIHR-118	34.25	2.95	-0.11	3.45	37.42	-0.08	-0.41	0.71	1.3	-4.26	0.07	0.16
IIHR-119 x IIHR-20-1	33.58	-0.23	-0.34	0.69	37.42	2.06	-0.42	0.15	1.46	5.26	0.01	0.08
IIHR-118 x IIHR-20-1	34.16	-1.3	3.17	6.36	36.92	3.7	0.02	2.01	1.48	-0.21	-0.0	0.0
Arka Manik x IIHR-46	32.16	1.36	0.18	0.74	39.72	7.05	0.35	10.25	1.33	-3.88	0.07	0.14
IIHR-43 x IIHR-46	33.66	0.37	-0.27	0.17	38.37	3.54	-0.45	1.34	1.21	-4.17	0.08	0.17
Arka Manik X IIHR-188	32.75	0.14	1.26	1.8	37.67	0.99	-0.45	0.05	1.52	3.95	0.05	0.11
Arka Jyothi (C)	33.25	0.23	0.21	4.67	37.42	2.18	0.8	1.41	1.24	-0.24	0.0	0.0
NS-295 (C)	34.75	0.13	0.01	0.67	37.13	-2.01	-0.45	3.49	1.53	-0.98	0.1	0.12
Kushboo	33.41	1.07	0.41	0.86	37.22	1.78	1.13	1.6	1.43	5.97	0.04	0.13
Madhubala	34.58	-0.23	0.4	1.48	37.33	-2.18	0.8	5.11	1.51	-7.59	0.34	0.53
Apoorva	34.41	-0.6	0.19	1.8	39.08	-3.26	0.44	7.39	1.6	1.45	0.0	0.01
CWH-7	34.8	1.85	-0.13	1.02	36.92	1.62	-0.44	0.02	1.31	9.31	0.09	0.34
Riya	34.83	0.75	-0.06	0.26	38.58	4.32	-0.45	2.5	1.42	-0.2	0.0	0.0

average genotype, which will respond well to a poor environment.

Similarly for the other biometrical characters, results presented in Table 3 and 4, revealed a marked difference among the number of hybrids grouped separately under two methods. Results indicated clearly about the change in cluster membership while adopting Freeman-Perkins model. In addition to this analysis, based on additional two year yield data (2005-06), optimum number of years required for inferring the stability of the above hybrids was made by testing the W_i values of subsequent years with the preceding value. It was observed four years (yield data) was sufficient (in addition to stable performance of Arka Jyothi and NS-295) to reach the stability of the evaluated genotypes as the measure of ecovalence till fourth year was significantly different from the earlier period and were on par from 5th year onwards.

To summarize, stability models (with R^2 = 81.4%-99.4%.) developed for yield and yield attributing biometrical characters of 14 watermelon F_1 hybrids indicated that Arka Jyothi followed by NS-295 were stable for wide range of cultivation for yield t ha^{-1}, as they possesses least ecovalence values as compared to other lines. Results further indicated that IIHR-178 x Arka Manik is suitable for poor environment. Thus, Arka Jyothi performed better (75.91 t ha^{-1}), across the years, followed by NS-295 (64.25 t ha^{-1}), than all the other hybrids. These two hybrids are widely used in crop breeding research and also cultivated for higher productivity across years and seasons. Hence, the message arising out from this present study is that breeders may exploit the use of Freeman-Perkins approach for performing stability research while analyzing multi-location/year/season trails, with a view to cluster the breeding materials/ genotypes based on their stability/adaptability to a specific situation and also to select promising lines for further hybridization programme and for commercial exploitation.

Table 3. Grouping of hybrids based on results of stability analysis (under ER and FP model) for 14 hybrids of watermelon

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
1.	Yield (t/ha) *ERmodel*	Riya	--	--
	FP model	Arka Jyothi (c), Riya, NS 295	IIHR-178 x Arka Manik	--
2.	Fruit length (cm) *ER model*	IIHR-178 x Arka Manik, Arka Manik x IIHR-46,Apoorva	IIHR-114 x IIHR-118, IIHR-118 x IIHR-20-1, IIHR-43 x IIHR-46, Arka Jyothi (C), Kushboo, Riya	IIHR-119 x IIHR-20-1, Arka Manik X IIHR-188, Madhubala
	FP model	IIHR-178 x Arka Manik, Apoorva	IIHR-114 x IIHR-118, IIHR-118 x IIHR-20-1, Arka Manik x IIHR-46, IIHR-43 x IIHR-46, Arka Jyothi (C), Kushboo, Riya	IIHR-119 x IIHR-20-1
3.	Fruit girth (cm) *ER model*	IIHR-119 x IIHR-20-1, IIHR-43 x IIHR-46, Arka Manik X IIHR-188, NS-295 (C), Madhubala, CWH-7	--	IIHR-119 x IIHR-20-1, Kushboo, CWH-7
	FP model	IIHR-114 x IIHR-118, IIHR-119 x IIHR-20-1, Arka Manik x IIHR-46, IIHR-43 x IIHR-46, Arka Manik X IIHR-188, Arka Jyothi (C), NS-295 (C), Kushboo, Madhubala, Apoorva, CWH-7	--	-- -
4.	Days to first male flower opening *ER model*	IIHR-119 x IIHR-20-1, Arka Manik X IIHR-188, NS-295 (C), Kushboo, Madhubala, Riya	IIHR-43 x IIHR-46, Apoorva	IIHR-114 x IIHR-118, CWH-7
	FP model	Arka Manik x IIHR-46, IIHR-43 x IIHR-46, Kushboo, Riya	IIHR-119 x IIHR-20-1, NS-295 (C), Madhubala, Apoorva	CWH-7
5	Days to first female flower opening *ER model*	IIHR-178 x Arka Manik, IIHR-118 x IIHR-20-1, IIHR-43 x IIHR-46, Arka Jyothi (C), Kushboo, CWH-7	IIHR-114 x IIHR-118, Arka Manik X IIHR-188, NS-295 (C)	
	FP model	Arka Manik X IIHR-188 IIHR-46, Riya	IIHR-178 x Arka Manik, IIHR-114 x IIHR-118	IIHR-119 x IIHR-20-1, Arka Manik x Arka Jyothi (C), NS-295 (C), Kushboo, Madhubala, CWH-7
6.	Rind thickness *ER model*	IIHR-118 x IIHR-20-1, Arka Jyothi (C), Apoorva, Riya	--	IIHR-119 x IIHR-20-1, Kushboo, CWH-7
	FP model	IIHR-118 x IIHR-20-1, Arka Jyothi (C), Apoorva, Riya	--	-
7.	TSS (%) *ER model*	IIHR-178 x Arka Manik, IIHR-118 x IIHR-20-1, Riya	--	--
	FP model	IIHR-178 x Arka Manik, IIHR-118 x IIHR-20-1, Riya	--	--

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

Table 4. Ranking among ideal watermelon hybrids under ER and FP models based on measure of ecovalence (W_i)

	Based on Eberhart-Russell (ER) Procedure		Based on Freeman-Perkins (FP) Procedure	
Character	Ideal Genotype	Ranked Wi values	Ideal Genotype	Ranked Wi values
1. Yield (t/ha)	NS-295	56.686	Arka Jyothi (c)	13.24
	Kushboo	105.441	NS 295	22.58
	Riya	189.434	Riya	122.54
2 Fruit length (cm)	IIHR-188 X IIHR-118	2.228	IIHR-188 X IIHR-118	2.503
	Apoorva	2.765	Apporva	2.621
	IIHR 43 X IIHR 46	4.432		
3. Fruit girth (cm)	Madhubala	0.069	IIHR 119 X IIHR-20-1	0.002
	IIHR 43 X IIHR 46	0.144	Madhubala	0.019
	IIHR 119 X IIHR-20-1	0.310	Arka Manik X IIHR-188	0.065
4. Days to first male	NS-295	0.527	IIHR 43 X IIHR 46	0.167
flower opening	Kushboo	0.603	Arka Manik X IIHR 46	0.735
5. Days to first female	Kushboo	0.384	Arka Manik X IIHR-188	0.054
flower opening	IIHR-188 X IIHR-118	0.538		
	IIHR-118 x IIHR-20-1	0.859		
6. Rind thickness(cm)	Arka Manik X IIHR 46	0.003	Arka Manik X IIHR 46	0.002
	Riya	0.003	NS-295	0.003
	NS-295	0.008	Riya	0.004
	Apoorva	0.011	Apoorva	0.009
7. T.S.S. (%)	Riya	0.122	Arka Manik X IIHR 46	0.061
	Arka Manik X IIHR 46	0.204	Riya	0.371
	IIHR-188 X IIHR-118	0.335	IIHR-188 X IIHR-118	0.781

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