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Genotype × environment interaction for root yield in radish

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ABSTRACT

Stability analysis helps in understanding the adaptability of genotypes over different environmental conditions and the identification of adaptable genotypes. The objective of the present study was to determine genotype × environment (GE) interaction and stability of radish genotypes and effect of different environments on root yield to understand its adaptation to varying environments. The study was conducted to assess yield stability across seasons in radish (*Raphanus sativus* L). Ten genotypes of radish were evaluated for fourteen characters under the Rabi, summer and Kharif seasons to study stability parameters. The genotype Kumbakonam local was stable for root yield in all seasons followed by Kanyakumari local 2 for leaf length, leaf area, root length, root diameter, fresh weight of the plant, root/leaf ratio and fresh weight of root per plant and had a linear response to season. The genotype Pusa Chetki had higher root yield during the Rabi season. Almost all characters were influenced by season except leaf width, root length, root diameter, fresh weight of leaves per plant, root/leaf ratio, dry weight of leaves per plant and plant fresh weight. The remaining traits had stability across seasons. Therefore the above said traits are important while exercising selection for different environments.

Keywords: Stability parameters; selection parameters; adaptability

INTRODUCTION

Radish (*Raphanus sativus* L) is a good source of vitamin C (ascorbic acid) and calcium, potassium and phosphorus. Radish is a popular choice for cultivation as it is fairly easy to grow with many varieties reaching maturity within 60 days. Generally the tuberous root is the portion eaten although the entire plant is edible and the tops can be used as a leafy vegetable. The leaves of radish are good source for extraction of protein on a commercial scale and radish seeds are a potential source of non-drying fatty oil suitable for soap making. Identification of high yielding and stable accession across variable environments is a continuing challenge to

plant breeders. The ultimate goal of the researchers is to develop accession or cultivars that are stable preferably over diverse growing conditions.

The characterization of stable accession is often complicated by the frequent occurrence of genotypes by environment interactions (CervenskiJanko et al 2011). Several stability analyses have been proposed to handle genotypes by environment interactions so as to recommend accessions that perform consistently better and are high yielders across different locations. Stability indices are either based on regression analysis or principal component analysis (Bernardo 2002). Genotypes performing well under a particular environment may or may not perform well over other environments due to genotype x environment interactions (GEI). A genotype with low GEI will have high stability. While developing a high yielding cultivar if proper care is not taken to select for both yield and stability of performance the end product could be a high yielding genotype suitable only for a particular environment. It is necessary to develop variety/hybrid with wide adaptability. Allard and Bradshaw (1964) suggested that selection of genotypes should be based on the smallest interaction with environment. They also stated that heterozygous and heterogeneous populations offer the least opportunity to produce varieties which show a small GEI. They used the term `individual buffering' for genotypes where individual members of a population are well buffered such that the population is well adapted to a wide range of environments.

Identifying a phenotypically stable variety is important to stabilize agricultural production. A proper understanding of the magnitude and nature of GEI and stability of the complex traits yield and yield components in radish would help in identification of stable genotypes. Information about the nature and magnitude of genetic divergence is essential for selection of diverse parents from which productive hybrids can be developed. This study was undertaken to determine how environment affected radish genotypes to identify stable performance of the genotypes.

MATERIAL and METHODS

Radish genotypes obtained from different sources (Table 1) were evaluated in 3 seasons. Plants were grown in a randomized complete block design with three replications. The soil was a well-drained sandy loam with pH >6. The soil was prepared and cultivated 3 times to obtain a loose and friable texture. Cow manure was applied along with urea, diammonium phosphate (DAP) and muriate of potash as per the recommended doses Anon (2005). The soil was formed into ridges and furrows in plots of 1 × 3 m size and seed was sown in lines on beds.

Table 1. Locations (India) from where genotypes were sourced

Genotype	Source
Pusa Chetki	Coimbatore
Paravai local	Nagapattinam
Sun 400	Bengaluru
Velankanni local	Velankanni
Bansankari local	Bengaluru
Kanyakumari local 1	kanyakumari
Kanyakumari local 2	Kanyakumari
Kumbakonam local	Kumbakonam
Mayavaram local	Mayiladudurai
Tanjavur local	Tanjavur

Irrigation was applied at a 3-days interval during the growing season. The insecticides chloriphyriphos or dimethoate were applied at 1.5 ml/l. Observations were recorded on 5 randomly selected plants in each genotype in each replication in each season for yield and its components for leaf length, leaf width, leaf area, number of leaves, root length, root diameter, fresh weight of leaves per plant, root/leaf ratio, dry weight of leaves per plant, dry weight of root per plant, dry weight of the plant, fresh weight of the plant, and fresh root weight per plant as well as ascorbic acid content. Mean (x), regression coefficient (b) and mean square deviation (S^2d) for each genotype were used to estimate parameters of stability according to Eberhart and Russell (1966). The density index (Ij) and phenotypic index (Pi) were estimated from mean data averaged over replications.

RESULTS and DISCUSSION

Development of stable varieties is the mission of plant breeders. A stable genotype is one that has low genotype × environment (G × E) interaction for agronomically important characters. Assessment of the G × E interaction is a pre-requisite to identify phenotypically stable genotypes. Regression analysis of the G × E interaction is a sound method to characterize genotypic response to varied environments (Sharma 1998). The regression approach in breeding was first used by Finley and Wilkinson (1963) who considered mean and regression as stability parameters.

Eberhart and Russell (1966) extended this approach and included the deviation from the regression as an additional parameter. The Eberhart and Russell model is the most informative, balanced and statistically simple. It is widely used by plant breeders to detect high yielding stable genotypes. Stability analysis of variance indicated differences among the genotypes for all characters indicating presence of variability among genotypes (Table 2). There were differences among environments for all characters implying variability among environments. The mean squares for the G × E interaction were significant for all traits indicating the differential response of genotypes to environment. The magnitude of the G × E interaction variance was smaller than for genotype and environmental variances individually for all traits. The G × E interaction effect was partitioned into linear (predictable) and non-linear (unpredictable) components for analysis for stability. High, significant and mean squares due to environment (linear) indicated differences among environments and their predominant effect on all traits likely due to variation in weather during sowing and crop maturation. It has been observed considerable differences between environments and their effect on traits that are likely due to variation in weather from sowing through root formation in radish. Significant pooled deviations for all characters indicated that the non-linear component was important in manifestation of the G × E interaction. The environmental indices reflected the poor and rich environments in terms of negative and positive indices respectively. From the mean of genotype (G), environment (E), G × E and the environmental index (I_j) it was found that the Rabi season seemed to be the rich environment where climatic conditions were conductive for growth and development of radish followed by the Kharif season as indicated by the highest yield. The summer season was the least beneficial. The positive expression of root length and diameter had positive environmental indices in Rabi season. The linear component of G × E interaction was significant for all characters indicated prediction about performance of most genotypes appeared feasible.

Significant mean squares due to pooled deviation of all characters indicated that genotypes differed with respect to their stability indicating an unpredictable G × E interaction. Eberhart and Russell (1966) used the stability parameters (i) genotypic mean (g_i), expressed as phenotypic index (Pi), (ii) regression value (b) (predictable linear response) and deviation from linearity (S^2d) (unpredictable linear response). According to this model an ideal stable genotype is one which confirms to a: (i) phenotypic index >0, represented by high genotypic mean (g_i >x), (ii) regression coefficient equal to unity (b=1) and (iii) deviation from regression is equal to zero (S^2d = 0). Such a genotype would be

Table 2. Analysis of variance for stability of different characters

Source	Genotype (G)	Environment (E)	Environment (linear)	G × E (linear)	Pooled deviation (non-linear)	Pooled error
Df	9	20	1	9	10	60
Leaf length	22.12*	34.18*	614.72*	5.13*	2.27*	0.35
Leaf width	17.81*	21.06*	416.38*	3.91*	1.86*	0.16
Leaf area	3508.81*	6533.48*	114246.86*	1732.99*	82.58*	0.25
# Leaves	6.68*	11.76*	111.11*	7.70*	5.48*	0.28
Root length	6.37*	62.97*	1104.44*	1.60*	14.05*	0.32
Root diameter	0.23*	0.50*	5.20*	0.20*	0.31*	0.07
Leaf fresh weight	106.30*	161.02*	2767.10*	38.44*	10.74*	0.28
Root/ leaf ratio	1.18*	4.61*	2.83*	0.76*	0.46*	0.02
Leaf dry weight	3.43*	6.50*	96.16*	2.67*	0.99*	0.36
Root dry weight	459.53*	354.33*	4729.99*	131.00*	117.76*	0.39
Plant dry weight	440.24*	183.26*	559.27*	19.09*	293.40*	46.13
Plant fresh weight	887.47*	1990.23*	32271.43*	621.21*	194.23*	0.32
Root yield/plant	1144.71*	1319.50*	21520.93*	341.98*	179.12*	0.30

*Significant at 5% level

suitable for general adaptation over all environmental conditions. The genotypes Paravai local, Bansankari local and Kanyakumari local 1 had a lower mean value than the grand mean for root yield. These genotypes can not be recommended even though Kanyakumari local 1 had a linear response over all environments. Genotype Pusa Chetki had a very high mean (Pi >0), high bi and high S^2d indicating it is highly sensitive to environment and the genotype performed well under favorable environments when inputs have no limitations; under poor environment they do not perform well. The linear responses b <1, b= 1 and b >1 occurred. In certain genotypes bi values were negative for leaf width, number of leaves, root diameter, root/ leaf ratio and dry weight of root per plant which could be attributed to the inadequacy of the scale used for analysis and for the inherent behavior of genotypes (Tables 3-9). Genotypes with coefficient >1.0 are adapted to more favorable growing conditions; those with a coefficient <1.0 are adopted to less favorable growing conditions. The regression coefficient ~1.0 is the most desirable. Smaller values of regression coefficient imply failure to take advantage of better conditions while larger values (b >1.0) imply to yield declines as conditions worsen. The genotypes Mayavaram local and Tanjavur local although having a positive grand mean had a higher/low linear response with significant/ negative non-linear response. The prediction of G × E interaction depends on the relative magnitude of the linear and non-linear components. In this study the linear regression being predominant assumed considerable practical significance. Significant deviation from linearity has arisen due to a specific cultivar × environment interaction (Joppa et al 1971). Of the genotypes tested Kanyakumari local 2 had a positive grand mean (Pi >0) as its bi ~1.0 with non-significant deviation from regression. This genotype responds consistently to a varying environment and can be exploited for crop improvement followed by Kanyakumari local 2. The other genotypes were influenced by environmental fluctuation and were unsuitable for uncertain environments. Among the characters studied it is inferred that root length, root diameter, root/leaf ratio, dry weight of root and fresh weight of the plant were correlated with root yield. Apart from yield these 5 traits had varied response to environment. The root length had a linear response in most genotypes. The root diameter and fresh weight of root per plant exhibited a linear response to environment in 3 genotypes; the root/leaf ratio and dry weight of root per plant were more sensitive to fluctuation in environment. The characters leaf length, leaf area and fresh weight of the plant exhibited linear response in 3 genotypes.

The data indicated that genotype Kumbakonam local exhibited stable performance on fresh root weight per plant in all environments and showed stability for leaf length, leaf width, number of leaves, root length and root diameter. The genotype

Table 3. Estimates of stability parameters for leaf length and width

Genotype	Leaf length (cm)			Leaf width (cm)		
	Mean (Pi)[a]	b	S^2d	Mean (Pi)	b	S^2d
Pusa Chetki	31.35 (8.75)**	1.01	-0.29	8.12 (0.59)**	0.25	-0.33
Paravai local	18.07 (-4.53)	1.61	0.82	6.63 (-0.90)	2.96	0.36
Sun 400	26.75 (4.15)**	0.66	-0.28	7.24 (-0.29)	-2.22	0.89
Velankanni local	29.74 (7.14)**	1.18	-0.24	8.18 (0.65)**	-0.09	-0.31
Bansankari local	27.60 (5.00)**	1.17	1.61	7.49 (-0.04)	-0.08	0.21
Kanyakumari local 1	25.23 (2.63)**	0.77	-0.13	7.86 (0.33)**	3.11	-0.18
Kanyakumari local 2	26.04 (3.44)**	1.04	9.91**	7.55 (0.02)**	0.97	2.78**
Kumbakonam local	24.71 (2.11)**	0.99	-0.19	7.14 (-0.39)	-0.54	0.01
Mayavaram local	24.06 (1.46)**	0.63	8.35**	6.88 (-0.65)	5.14	1.51**
Tanjavur local	23.75 (1.15)**	0.94	-0.31	8.21 (0.68)**	0.50	1.02
Grand mean	22.60			7.53		

**Mean values significantly above grand mean in desirable direction, P <0

[a]Values in parentheses indicate phenotypic index (Pi)

Table 4. Estimates of stability parameters for leaf area and number of leaves

Genotype	Leaf area (cm^2)			Number leaves		
	Mean (Pi) [a]	b	S^2d	Mean (Pi)	b	S^2d
Pusa chetki	259.52 (60.06)**	1.27	14.18	7.83 (-2.69)	-0.96	-0.28
Paravai local	122.46 (-77.00)	1.32	14.88	13.41 (2.89)**	1.15	7.20
Sun 400	197.72 (-1.74)	0.97	8.35	8.74 (-1.78)	0.80	-0.02
Velankanni local	249.06 (49.60)**	1.43	164.51**	13.25 (2.73)**	0.28	4.10
Bansankari local	211.36 (11.90)**	1.46	109.02	10.12 (-0.40)	1.56	2.05
Kanyakumari local 1	202.88 (3.42)**	1.05	16.09	8.74 (-1.78)	1.85	10.15**
Kanyakumari local 2	201.43 (1.97)**	0.69	395.89**	7.43 (-3.09)	1.53	23.36**
Kumbakonam local	180.79 (-18.67)	1.00	5.26	11.50 (0.98)**	0.95	0.34
Mayavaram local	169.82 (-29.64)	0.38	63.23	13.75 (3.23)**	1.14	4.71
Tanjavur local	199.54 (0.08)**	0.44	31.96	10.46 (-0.06)	1.70	0.31
Grand mean	199.46	10.52				

**Mean values significantly above grand mean in desirable direction, P <0

[a]Values in parentheses indicate phenotypic index (Pi)

Table 5. Estimates of stability parameters for root length and diameter

Genotype	Root length (cm)			Root diameter (cm)		
	Mean (Pi) [a]	b	S^2d	Mean (Pi)	b	S^2d
Pusa Chetki	25.65 (1.73)**	1.06	29.67**	2.08 (0.10)**	1.69	-0.03
Paravai local	24.54 (0.62)**	0.99	2.08	2.40 (0.42)**	1.43	-0.03
Sun 400	19.93 (-3.99)	0.97	5.49	1.94 (-0.04)	1.57	-0.04
Velankanni local	22.81 (-1.11)	1.27	4.31	2.58 (0.60)**	0.99	-0.03
Bansankari local	22.67 (-1.25)	0.94	5.87	1.89 (-0.09)	1.15	-0.03
Kanyakumari local 1	23.30 (-0.62)	1.07	24.96**	1.43 (-0.55)	0.75	-0.05
Kanyakumari local 2	23.83 (-0.09)	0.85	2.43	1.50 (-0.48)	1.07	-0.02
Kumbakonam local	25.62 (1.70)**	1.05	23.80**	1.45 (-0.53)	1.00	-0.03
Mayavaram local	26.16 (2.24)**	0.86	37.22**	2.37 (0.39)	-0.53	2.73**
Tanjavur local	24.66 (0.74)**	0.94	1.51	2.19 (0.21)	0.89	-0.04
Grand mean	23.92			1.98		

**Mean values significantly above grand mean in desirable direction, P <0

[a]Values in parentheses indicate phenotypic index (Pi)

Table 6. Estimates of stability parameters for fresh weight of leaves per plant and root/leaf ratio

Genotype	Fresh weight of leaves/plant (g)			Root/leaf ratio		
	Mean (Pi) [a]	b	S^2d	Mean (Pi)	b	S^2d
Pusa Chetki	40.15(1.10)**	1.39	11.85	4.47(1.80)**	2.39	-0.21
Paravai local	24.77(-14.28)	1.08	-0.10	2.79(0.12)**	-4.63	-0.27
Sun 400	48.92(9.87)**	0.87	1.14	1.45(-1.22)	-1.44	-0.29
Velankanni local	34.97(-4.08)	1.01	0.48	2.12(-0.55)	6.27	-0.15
Bansankari local	36.53(-2.52)	0.37	27.52**	2.38(-0.29)	1.67	1.73**
Kanyakumari local 1	43.82(4.77)**	1.51	27.43**	2.17(-0.50)	-0.54	0.75
Kanyakumari local 2	44.98(5.93)**	0.79	21.51**	2.44(-0.23)	3.72	-0.30
Kumbakonam local	36.80(-2.25)	1.35	-0.07	3.27(0.60)**	2.19	0.17
Mayavaram local	37.22(-1.83)	0.51	14.97	3.10(0.43)**	-2.06	-0.28
Tanjavur local	42.35(3.30)**	1.12	-0.19	2.55(-0.12)	2.43	-0.07
Grand mean	39.05			2.67		

**Mean values significantly above grand mean in desirable direction, P <0

[a]Values in parentheses indicate phenotypic index (Pi)

Table 7. Estimates of stability parameters for leaf and root dry weights per plant

Genotype	Leaf dry weight/plant (g)			Root dry weight/plant (g)		
	Mean (Pi) [a]	b	S^2d	Mean (Pi)	b	S^2d
Pusa Chetki	9.17(1.03)**	0.98	-0.36	63.49 (14.42)**	1.77	161.72**
Paravai local	4.93(-3.21)	0.60	0.63	36.91 (-12.16)	0.58	11.76
Sun 400	9.75(1.61)**	1.03	0.52	36.13 (-12.94)	1.08	-0.37
Velankanni local	7.20(-0.94)	1.11	-0.29	36.44 (-12.63)	-0.02	184.26**
Bansankari local	7.53(-0.61)	0.75	0.05	41.27 (-7.80)	0.75	-0.26
Kanyakumari local 1	9.33(1.19)**	0.74	4.41**	48.04 (-1.03)	1.18	-0.12
Kanyakumari local 2	9.40(1.26)	0.71	-0.35	52.50 (3.43)**	1.04	205.79**
Kumbakonam local	7.75(-0.39)	2.43	0.51	60.10 (11.03)**	0.69	127.89**
Mayavaram local	7.66(-0.48)	0.78	1.46**	60.87 (11.80)**	1.61	466.09**
Tanjavur local	8.65(0.51)**	0.89	-0.25	54.99 (5.92)**	1.33	17.02
Grand mean	8.14			49.07		

**Mean values significantly above grand mean in desirable direction, P <0

[a]Values in parentheses indicate phenotypic index (Pi)

Table 8. Estimates of stability parameters for plant dry and fresh weights

Genotype	Plant dry weight (g)			Plant fresh weight (g)		
	Mean (Pi) [a]	b	S^2d	Mean (Pi)	b	S^2d
Pusa chetki	72.66 (15.36)**	1.48	-2.11	161.08 (34.25)**	1.46	6.35
Paravai local	41.84 (-15.46)	0.83	-25.96	88.40 (-38.43)	1.08	0.20
Sun 400	45.89 (-11.41)	1.16	151.00**	111.62 (-15.21)	1.01	28.65
Velankanni local	43.63 (-13.67)	2.09	1290.97**	100.26 (-26.57)	1.80	1416.20**
Bansankari local	48.79 (-8.51)	0.94	-33.12	111.56 (-15.27)	1.09	0.45
Kanyakumari local 1	57.37 (0.07)**	0.18	130.97**	129.34 (2.51)**	1.27	25.90
Kanyakumari local 2	61.89 (4.59)**	1.52	-39.61	136.97 (10.14)**	0.69	5.29
Kumbakonam local	67.85 (10.55)**	0.94	-8.58	146.55 (19.67)**	0.38	55.97
Mayavaram local	68.52 (11.22)**	0.48	121.20**	143.58 (16.75)**	0.70	369.87**
Tanjavur local	64.53 (7.23)**	0.39	287.95**	138.93 (12.10)**	0.53	30.25
Grand mean	57.30			126.83		

**Mean values significantly above grand mean in desirable direction, P<0.

[a]Values in parenthesis indicate phenotypic index (Pi).

Table 9. Estimates of stability parameters for fresh root weight per plant

Genotype	Fresh root weight per plant (g)		
	Mean (Pi) [a]	b	S^2d
Pusa Chetki	113.30(28.84)**	1.95	229.80**
Paravai local	62.62(-21.84)	0.74	53.09
Sun 400	61.26(-23.20)	1.13	19.09
Velankanni local	62.52(-21.94)	0.94	856.98**
Bansankari local	72.24(-12.22)	0.70	54.33
Kanyakumari local 1	82.17(-2.46)	1.02	50.97
Kanyakumari local 2	91.24(6.78)**	0.93	56.46
Kumbakonam local	103.38(18.92)**	1.22	23.63
Mayavaram local	101.82(17.36)**	0.44	444.07**
Tanjavur local	94.05(9.59)**	1.19	-0.239
Grand mean	84.46		

**Mean values significantly above grand mean in desirable direction, P <0

[a]Values in parentheses indicate phenotypic index (Pi)

Pusa Chetki had higher yield under favorable environment ie Rabi season. Thus these would be recommended for environmental conditions of Kariakal region of Puducherry.

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