J. AMER. SOC. HORT. SCI. 120(2):325-328. 1995.

Yield and Fruit Size Stability Differs among Bell Pepper Cultivars

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Additional index words. Capsicum annuum, cultivar × environment interactions, adaptability

Abstract. **Bell pepper *(Capsicum annuum* L.) cultivars were grown in nine Florida environments to evaluate phenotypic stability of marketable fruit yield (t-ha-‘) and mean fruit size (g/fruit). A stable cultivar excelled for a particular trait when grown in either favorable or unfavorable environments. A stable cultivar for a given trait was defined as one with an individual mean greater than the grand mean (mean of all cultivars) (x > X), a regression coefficient (b_i) ≤ 1 (individual genotypic mean regressed against environmental means), nonsignificant deviation mean squares from regression (S^2d), coefficient of linear determination (R^2) > 0.50, and coefficient of variation (cv) < the pooled cv. ‘Ssupersweet 860’, ‘Whopper Improved’, and ‘Ranger’ were stable for mean marketable fruit weights and fruit size, and ‘Ssupersweet 860’ and ‘Whopper Improved’ were stable for mean fruit size. Bell pepper cultivars were differentiated for phenotypic stability of yield and fruit size or adaptability to diverse environments. Therefore, through stability analyses, bell pepper plant breeders can identify cultivars or select advanced breeding lines that express adaptability for fruit yields or size to diverse environmental conditions or cultural practices.**

Stability of yield or fruit quality traits is measured to determine adaptation of specific cultivars or advanced breeding lines to an array of production environments. Environments may vary in cultural or management practices and climatic or edaphic conditions. Plant breeders, through stability analyses, can determine if existing cultivars or selections are adapted to favorable, unfavorable, or both environmental conditions.

Yield stability has been evaluated on solanaceae crops including potato *(Solanum tuberosum* L.) (Dhiman, et al., 1986; Lynch and Kozub, 1988; Tai, 1971), tomato *(Lycoperscion esculentum* Mill.) (Berry, et al., 1988; Cuartero and Cubero, 1982; Izquierdo, et al., 1980; Ortiz and Izquierdo, 1994; Poysa, et al., 1986; Stoffella, et al, 1984), and sweet pepper *(Capsicum annuum* L.) (Carillo, et al., 1991).

Phenotypic yield stability of a particular cultivar can be assessed by use of the regression coefficient (b_i) derived from regression models consisting of individual cultivar means for a particular trait as the dependent variable and environmental means (mean of all cultivars within an environment) as the independent variable (Finlay and Wilkinson, 1963) and the deviation from linear regression mean squares (S^2d) (Eberhart and Russell, 1966). Other stability parameters have been developed and have been reviewed by Becker and Leon (1988) and Lin et al. (1986).

Bell peppers were grown on >8000 ha and were valued at $179 million during the 1992-1993 crop year in Florida (Florida Agricultural Statistics, 1994). Bell peppers are grown under diverse cultural practices, soil types, and climates in Florida (Hochmuth, 1988). The purpose of this investigation was to assess fruit yield and size stability of several bell pepper cultivars grown in differing Florida environments.

Material and Methods

Cultivar performance trial. ‘Jupiter’, ‘Early Calwonder’, ‘Ssupersweet 860’, ‘Orobelle’, ‘Memphis’, ‘Bell Captain’, ‘Galaxy’, ‘Gator Belle’, ‘Whopper Improved’, ‘Ranger’, ‘Rebell’, ‘Capistrano’, ‘Boynton Bell’, and ‘King Arthur’ bell peppers were transplanted at seven locations in Florida during 199 1. Each trial utilized the characteristic raised, full-bed polyethylene mulch cultural system (Hochmuth, 1988). Production season, soil type, fertilization rate, planting arrangement, plant population, and number of harvests are presented in Table 1. A randomized complete-block experimental design with each cultivar replicated four times was used for each experiment.

Fruit were harvested from each plot, graded into marketable and cull, and the marketable fruit were counted and weighed. For each plot, marketable fruit number and weight for all harvests were combined to obtain seasonal mean fruit size (g/fruit) and marketable yields ($t \cdot ha^{-1}$).

Statistical analyses. Combined analyses of variance (ANOVA)

Received for publication 1 Aug. 1994. Accepted for publication 7 Nov. 1994. Florida Agricultural Experiment Station Journal Series No. R-03971. We gratefully acknowledge the financial support provided by the Florida Bell Pepper Growers’ Exchange. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

Table 1. Soil type and cultural practices used for bell pepper performance trails in nine Florida environments.

Environment			Arrangement			Fertilizer applied ($kg\cdot ha^{-1}$)			Plant population	Harvest'
			Spacing between:							
Location	Season	Soil type	Beds (m)	Plants (m)	Rows/bed (no.)	N	P	K	(plants/ha)	(no.)
Boyoton Beach	Fall	Oldsmar sand	1.82	0.20	2	336	72	491	53,797	3
Bradenton	Spring	Eau Gallie fine sand	1.52	0.27	2	316	51	364	48,027	3
	Fall	Eau Gallie fine sand	1.52	0.24	2	316	51	364	48,027	4
Ft. Pierce	Spring	Oldsmar fine sand	2.13	0.25	2	145	129	263	36,906	3
	Fall	Oldsmar fine sand	2.13	0.25	2	145	129	263	36,906	4
Gainesville	Spring	Arrendondo fine sand	1 .22	0.30	1	170	10	160	27,322	2
Immokalee	Fall	Immokalee fine sand	1.83	0.25	2	224	90	280	43,055	3
Loxahatchee	Spring	Riveera sand	1.82	0.25	2	364	95	459	43,631	4
Quincy	Spring	Dothan loamy fine sand	1.83	0.30	2	218	30	181	35,860	3

'Harvest number indicates total number of harvests during the season.

were performed for marketable fruit yield and mean fruit size. For the combined analyses, a split-block experimental design was used with environments as the main block and cultivars as the split-block. Cultivar × environment interactions were significant for marketable fruit yield and mean fruit size (Table 2), therefore, subsequent stability analyses were performed.

Regression coefficient (b_1) (Finlay and Wilkinson, 1963) was a stability parameter calculated for each cultivar from the equation model

$$A = b_o + b_1 x_1$$

where A is the mean of an individual cultivar for a given trait, b_o is the Y-axis intercept, b_1 is the linear regression coefficient or slope, and x_1 is the environmental mean (mean from all cultivars within an environment) for a given trait. Attest was used to test the hypothesis:

$$H_o: b_1 = 1$$

The deviation from linear regression mean squares (S^2d) (Eberhart and Russell, 1966) was the second stability parameter. A F test (S^2d was tested against the pooled error mean square) was used to test if S^2d was significant for each cultivar.

The coefficient of linear determination *(R^2)* was calculated for each linear regression model and served as the third stability parameter (Gull et al., 1989; Stoffella et al., 1984). Genotypes with R^2 values >50% were considered stable since 50% or more of the ANOVA sum of squares or variation would be attributed to linear regression, whereby <50% of the total variation would be unex-

Table 2. Mean squares from combined analysis of variance for marketable hell pepper fruit yield and mean fruit size.

Source of variation	df	Mean squares: Fruit yield ($t\cdot ha^{-1}$)	Fruit size (g/fruit)
Environment (E)	8	6228**	62,846**
Replication/E	27	76	232
Cultivar (C)	13	141**	2398**
C × E	104	51**	308**
Experimental error	351	16	118

**Significant at *P* = 0.01.

Table 3. Stability parameters for marketable fruit yield of 14 bell pepper cultivars.

Cultivar	Mean fruit yield ($t\cdot ha^{-1}$)	Regression coefficient (b_1)	Deviations mean square from regression (S^2d)	Coefficient of linear determination *(R^2)*	Coefficient of variation (cv)
Jupiter	21.1	1.06	16.4	0.84	22.7
Early Calwondcr	19.0	0.98	38.5*	0.83	23.8
Ssupersweet 860	24.3	0.84*	5.7	0.81	17.2
Orobelle	22.4	0.96	52.7	0.78	22.4
Memphis	21.7	1.10	40.4	0.85	22.1
Bell Captain	21.5	1.02	23.4	0.79	25.0
Galaxy	23.1	1.05	49.7	0.77	25.5
Gator Belle	25.2	1.17	55.8	0.82	22.0
Whopper Improved	23.3	1.00	24.8	0.83	19.8
Rebell	22.6	1.02	34.6	0.82	21.6
Ranger	22.9	0.77**	12.6	().82	16.1
Capistrano	21.5	1.01	43.0*	0.84	20.8
Boynton Bell	27.2	1.27*	19.0**	0.76	27.2
King Arthur	23.7	0.72**	27.1*	0.8 1	15.2
X	22.8	1 .0			21.5

*,**Significant at *P* = 0.05 or 0.01. Indicates that b_1 is significantly different from unity at *P* = 0.05 or 0.01.

Table 4. Stability parameters for mean fruit size of 14 bell pepper cultivars.

Cultivar	Mean fruit size (g/fruit)	Regression coefficient (b_1)	Deviations mean square from regression (S^2d)	Coefficient of linear determination (R^2)	Coefficient of linear determination (cv)
Jupiter	146	1.05	318	0.82	11.1
Early Calwonder	117	0.89	108	0.88	8.5
Supersweet 860	144	1.01	147	0.88	8.4
Orobelle	136	1.03	309*	0.88	9.1
Memphis	141	1.11	91	0.95	6.1
Bell Captain	142	0.93	327**	0.87	8.1
Galaxy	144	1.01	310**	0.89	7.9
Gator Belle	137	1.03	351	0.87	9.2
Whopper Improved	147	1.06	163	0.92	7.1
Rebell	131	1.05	415**	0.87	10.1
Ranger	131	0.83**	253**	0.87	7.9
Capistrano	149	0.97	445**	0.86	8.6
Boynton Bell	152	0.99	203	0.80	10.5
King Arthur	154	1.05	779**	0.90	11.1
X	142	1.0			8.8

*** Significant at P = 0.05 or 0.01. Indicates that b_1 is significantly different from unity at $P = 0.01$.

plained or experimental error.

Coefficient of variation (cv) (Francis and Kannenberg, 1978) was calculated as

cv = (s/x) × 100

where cv is the coefficient of variation, S is the standard deviation and x is the mean of a given trait for a specific cultivar.

Stability definition. A cultivar was considered to possess stability (adaptability to favorable and unfavorable environment) for a given trait if the individual cultivar mean was greater than the grand mean (x > X), $b_1 \leq 1$, deviations from S^2d was nonsignificant, $R^2 > 0.50$, and the cv was less than the pooled mean cv.

Results and Discussion

Bell pepper yields and fruit size were significantly affected by the environment in which they were grown (Table 2). Mean marketable bell pepper fruit yields of the 14 cultivars grown at the nine environments were quite variable and ranged from 11.9 to 44.7 $t \cdot ha^{-1}$ (Data not shown). This suggested that the cultivar evaluation sites covered a diverse range of favorable and unfavorable environments for production of bell pepper in 1991. Mean fruit sizes (g/fruit) were also variable and ranged from 71 to 185 at the nine environments (Data not shown).

Marketable fruit yield and fruit size were significantly influenced by cultivar (Table 2). Mean fruit yields for the 14 cultivars ranged from 19.0 to 27.2 $t \cdot ha^{-1}$ (Table 3) and mean fruit sizes ranged from 127 to 154 g/fruit (Table 4). However, environment and cultivar significantly interacted in their effects on marketable fruit yield and mean fruit size (Table 2). Since cultivar and environment significantly interacted, stability analyses could be performed.

Based on our stability definition (material and methods), ‘ Ssupersweet 860’, ‘Whopper Improved’, and ‘Ranger’ had phenotypic stability for marketable fruit yield. Using b_i, S^2d, and comparison of cultivar means (x vs. X), Carillo et al. (1991) reported stability differences among sweet pepper cultivars for yield, fruit number per plant, fruit size (g/fruit), and plant height.

The parameter R^2 was not useful in our study as a stability index for marketable fruit yield, since each model had $R^2 > 0.50$. Stoffella et al. (1988) also reported $R^2 > 0.50$ for each tomato cultivar model evaluated for marketable fruit yield stability, indicating the ineffectiveness of R^2 as a stability parameter. However, Gull et al. (1989) reported $R^2 < 0.50$ when measuring stability of percent citric acid, percent soluble solid, ascorbic acid, color a/b, percent N, and percent dry weight in several cultivars of fresh marketable tomato fruit.

As previously defined, ‘Ssupersweet 860’ and ‘Whopper Improved’ were stable for mean fruit size (Table 4). As with marketable fruit yields, R^2 for fruit size model was not a useful stability parameter, since each cultivar had $R^2 > 0.50$.

The results indicated that bell pepper cultivars could be differentiated for stability of marketable fruit yield and mean fruit size by using our stability definition. ‘Ssupersweet 860’ and’ Whopper Improved’ were considered stable for marketable fruit yield and mean fruit size and ‘Ranger’ was considered stable for mean fruit size. The S^2d was not an effective parameter to screen for phenotype stability of bell pepper fruit yield or size.

Plant breeders should consider stability analyses as a method of identifying bell pepper cultivars or selecting advanced breeding lines for adaptability to diverse environmental production areas.

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