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Stability of Strawberry Genotypes in the Annual Hill Cultural System

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Abstract. **Plants of 'Selva', 'Pajaro', and three Univ. of Florida strawberry *(Fragaria* × *ananassa* Duch.) selections were grown near Dover, Fla., for five seasons using the annual hill cultural system. Genotype × environment interactions were significant for both marketable yield and fruit weight; therefore, stability analyses were performed. None of the genotypes had consistently high marketable yield, but one of the selections, FL M-1350, had relatively large and stable average fruit size. A genotype was desirable if it had a mean yield (or fruit weight) above the grand mean of all five genotypes, a regression coefficient ≤1, and a nonsignificant deviation from regression.**

Strawberry production in Florida is concentrated in the west-central region of the state, between Tampa and Lakeland, on ≈2000 ha (Freie and Young, 1990). A mild and sunny climate with relatively few damaging freezes makes this area well suited for winter strawberry production. Strawberry plants are planted annually in October on raised beds that have been fumigated and covered with black polyethylene mulch. The harvest season usually starts in December, with heaviest production in January through March.

Recently, west-central Florida growers mostly have planted the California cultivars Selva and Pajaro to satisfy market demands. 'Selva' is prized for its long shelf life and its ability to produce some fruit in November and early December. 'Pajaro' is popular because its fruit is generally firm, attractive, and flavorful. These cultivars have been relatively low-yielding in Florida (Chandler et al., 1989). Contributing to the low yield of 'Pajaro' is its extreme susceptibility to anthracnose fruit rot incited by *Colletotrichum* spp. (Howard et al., 1985), the most serious disease affecting strawberries in Florida. Anthracnose fruit rot and most other fruit rots affecting strawberries in Florida are favored by warm, rainy weather. Average monthly temperatures and rainfall amounts during the strawberry growing season can be variable from year to year (Table l), contributing to variability in the incidence of disease.

A major goal of the Univ. of Florida's strawberry breeding program is to identify genotypes that are large-fruited and high-yielding regardless of environmental conditions. Published yield stability studies on strawberry appear to be limited to strawberries grown in matted rows in the north-central region of the United States (Chandler and Hill, 1988; Hancock, 1985; Hanson, 1989; Pritts and Luby, 1990). We, therefore, assessed yield and fruit size stability of 'Selva', 'Pajaro', and three Univ. of Florida selections grown in Florida using the annual hill cultural system.

Description of trials. Plants of 'Selva', 'Pajaro', and the Univ. of Florida selections, FL 79-1126, FL 81-1350, and FL 82-1452, were grown at the Agricultural Research and Education Center, Dover, Fla., during the 1985-86 through 1989-90 seasons. The research center is located in the heart of the commercial strawberry-growing area, ≈21 km east-northeast of Tampa Bay, at 28°N lat. and 23 m above sea level. The soil type is a Seffner fine sand (sandy, siliceous, hyperthermic Quartzipsammentic Haplumbrepts) .

Single-crown transplants were set each October through black polyethylene mulch on standard (Albregts and Howard, 1984) two-row raised beds that had been fumigated with 336 kg of MC98-2 (98% methyl bromide, 2% chloropicrin) per bedded hectare and fertilized with 10N-4P-10K at a rate of 2.2 $t \cdot ha^{-1}$ before planting. One-fourth of the fertilizer was broadcast before bed preparation; the remainder was banded 2.5 to 5.0 cm deep in the bed center. One-half of the N was applied in the form of sulfur-coated urea; the other half in the form of ammonium nitrate. Plants were spaced 30 cm apart in the row, with 30 cm between rows. Five plots of each clone were planted in a randomized complete block design. Each plot contained 14 plants. Pesticides and water (sprinkler irrigation) were applied as needed. Fruit were harvested, graded, counted, and weighed twice a week during January through March.

Statistical analysis. A combined analysis

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Table 1. Mean temperature (°C) and rainfall (mm) at the Agricultural Research and Education Center, Dover, Fla.

Month	Season 1985–86	1986–87	1987–88	1988–89	1989–90
October					
Temperature	26	24	21	22	23
Rainfall	30	210	80	260	60
November					
Temperature	22	24	20	21	20
Rainfall	60	40	110	180	60
December					
Temperature	14	19	17	16	13
Rainfall	30	80	10	30	140
January					
Temperature	15	15	14	19	19
Rainfall	80	100	100	80	20
February					
Temperature	18	17	14	18	20
Rainfall	50	70	50	10	130
March					
Temperature	18	19	18	21	20
Rainfall	120	350	170	40	30

Table 2. Mean squares from combined analysis of variance for marketable strawberry fruit yields and fruit weight.

Source of variation	df	Marketable yield ($t \cdot ha^{-1}$)	Fruit wt (g)
Environments (Env)	4	185.5**	6.4
Replication/Env	20	12.5	3.4
Genotype (Gen)	4	744.9**	29.1
Env × Gen	16	51.5**	4.3*
Experimental error	80	9.4	2.0

*,**Significant F test at $P = 0.05$ and 0.01, respectively.

Table 3. Stability estimates for marketable fruit yield of several strawberry genotypes grown at Dover, Fla.

Genotype	Marketable fruit yield ($t \cdot ha^{-1}$)	b_1	Deviation from regression (mean square)	CV
Selva	13.4	0.28	42.3*	30.2
Pajaro	15.2	1.68	0.7	15.2
FL 79-1126	24.9	1.53	12.5*	17.4
FL 81-1350	25.3	1.76	40.9	23.8
FL 82-1452	19.2	−0.25	9.7	18.3
$\bar{X}$	19.6	1.00		15.7

*Significant F test at $P = 0.05$.

Table 4. Stability estimates for fruit weight of several strawberry genotypes grown at Dover, Fla.

Genotype	Fruit wt (g)	b_1	Deviation from regression (mean square)	CV
Selva	15.4	−0.30	2.43	8.85
Pajaro	16.9	2.58	0.42	10.17
FL 79-1126	15.9	0.11	3.62**	5.40
FL 81-1350	17.4	0.55	2.38	5.74
FL 82-1452	18.0	2.03	3.56	14.52
$\bar{X}$	16.7	1.00		8.40

**Significant F test at $P = 0.01$.

of variance (ANOVA) across years was performed with environments (years) and genotypes considered fixed effects. Appropriate error terms were used to test significance among environments, genotypes, and environment × genotype interactions. The marketable yield and fruit weight stability of each genotype was assessed using two indices: coefficient of variability (cv) and linear regression analysis (Eberhart and Russell, 1966; Finlay and Wilkinson, 1963). The deviation from linear regression mean squares were tested using the pooled error mean square. Genotypes with a mean yield above the grand mean yield (mean of all five genotypes) and $b_1 > 1$ were considered unstable and only adapted to favorable environments. Genotypes with a mean yield below the grand mean and $b_1 < 1$ were considered stable but low-yielding. Genotypes with a mean yield below the grand mean and $b_1 > 1$ were considered unstable and low-yielding. We considered a genotype desirable when it had a mean yield (or fruit weight) above the grand mean, $b_1 \leq 1$, and a nonsignificant deviation from regression.

Main effects of environments (years) and genotypes from the combined ANOVA were significant for marketable yield (Table 2). The mean yearly marketable yield ranged from 16.4 to 23.3 $t \cdot ha^{-1}$, a 42% increase from the worst year to the best year, suggesting that both favorable and unfavorable environments had occurred during the evaluation period. Genotype × environment interactions were significant for both marketable yield and fruit weight (Table 2), indicating that stability analyses were appropriate.

The stability analyses showed that none of the genotypes had consistently high marketable yields (Table 3). 'Selva' was stable but low-yielding, while 'Pajaro' was both unstable and low-yielding. The Florida-bred genotypes had a higher average yield than the California cultivars but were unstable. FL 79-1126 and FL 81-1350, with $b_1 > 1$, can only be considered adapted to favorable environments, while FL 82-1452, with $b_1 <$ 0, is an anomaly.

Only FL 81-1350 had a mean average fruit weight above the grand mean, $b_1 < 1$, and a nonsignificant deviation from regression (Table 4). A below-average cv is further proof of FL 81-1350's fruit size stability. However, fruit of this selection bruise easily and, therefore, are not suitable for long-distance shipping. FL 82-1452 had impressive average fruit weight, but, like 'Pajaro', its average fruit weight varied considerably from year to year.

Phenotypically stable cultivars would be of great benefit to the Florida strawberry industry. The use of such cultivars might result in a more stable market; growers could produce predictable supplies and pack a consistent product. 'Selva' and 'Pajaro', the current industry standards, cannot be considered phenotypically stable based on the results of this study, but are grown extensively because they have acceptable fruit quality and, in the case of 'Selva', can produce some fruit in November and early December.

What are the prospects of developing phenotypically stable strawberry cultivars for west-central Florida? The heritability of yield and fruit weight stability has not been investigated in strawberry, but is probably low based on work done in other crops (Becker and Leon, 1988). Increasing the stability of yield may be possible, however, by developing genotypes with greater fruit rot resistance. Such clones likely would be less vulnerable to periods of rainy weather and high humidity. FL 79-1126 is highly resistant to anthracnose fruit rot, but susceptible to gray mold (incited by *Botrytis cinerea* Pers. ex Fr.) (C.M.H., unpublished data). Despite the difficulty that may be encountered in generating stable genotypes, the evaluation of existing and future genotypes for stability will be relatively easy. Stability estimates can be calculated routinely using powerful statistical software packages such as SAS (SAS Institute, 1979).

An alternative to the development of more stable genotypes is the modification of cultural and pest management practices so that genotypes like FL 79-1126, which are adapted only to favorable environments, are less likely to be exposed to unfavorable environments.

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