Proc. Fla. State Hort. Soc. 117:83-85. 2004.

REFEREED PAPER

FRUIT DEVELOPMENT PERIOD IN STRAWBERRY DIFFERS AMONG CULTIVARS, AND IS NEGATIVELY CORRELATED WITH AVERAGE POST BLOOM AIR TEMPERATURE

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Additional index words. Fragaria × *ananassa*, fruit harvest, flower position

Abstract. **A study was conducted in Queensland, Australia during the winter of 2000 to determine the length of time from anthesis to mature fruit [i.e., the fruit development period (FDP)] for strawberry (*Fragaria* × *ananassa* Duch.) grown in an open field, plasticulture system, identical to the system used for strawberry production in Florida. This information could be useful for developing a model that growers could use to predict their peak harvest periods. From 15 June to 17 Aug., open flowers of several cultivars were tagged. Then the dates on which these tagged flowers became mature fruit were recorded. These data were used to calculate the FDP for each fruit. FDP ranged from 24 to 44 days, was dependent on cultivar, and negatively correlated with the 4-week post bloom mean air temperature.**

The winter strawberry industries in Florida and Queensland, Australia produce fruit on over 7,000 and 1,000 acres, respectively. Fruit are produced from late fall to early spring, but the highest yields occur during a 3- to 4-week period in late winter. In 2004, the Florida industry harvested 3.5 million

This research was supported by the Florida Agricultural Experiment Station and the Department of Primary Industries and Fisheries Queensland, and approved for publication as Journal Series No. R-10334.

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flats of fruit (each containing 9-12 lb of product) during a 3-week period from 27 Feb. to 18 Mar. (Chris Smith, BBI Produce, Florida, personal communication). Profitably marketing such a large quantity of fresh strawberries can be challenging, especially when the period of peak harvest (usually lasting about 10 d) cannot be predicted accurately. Sellers and chain store buyers need to know what production will be several weeks in advance in order to optimize sales and price. A model that estimates future production could be very helpful to the Florida and Queensland strawberry industries. A first step in developing such a model is to determine accurate estimates for the number of days from open flower to horticulturally mature fruit, a variable that has been termed *fruit development period* (FDP) (Darrow, 1966).

Fruit cultivars have a characteristic number of days from bloom to maturity (Westwood, 1978). For example, the FDP for 'McIntosh' apple ranges from 125 to 145 d, while the FDP for 'Golden Delicious' apple ranges from 140 to 160 d. Air temperatures during fruit development account for some of the variation in FDP. Westwood (1978) states that pears, apples, and peaches grown at relatively high temperatures during cell division (the first 4 to 8 weeks after bloom, depending on species) mature in fewer days than those grown at lower post-bloom temperatures.

Recent texts (Galletta and Himelrick, 1990; Hancock, 1999) indicate that the average FDP in strawberry is about 30 d, but research papers documenting this fact are scarce. Wilson and Giamalva (1954), following the fruit development of four cultivars over three seasons in Louisiana, found that most of the fruit ripened in 23 to 28 d. Statements concerning the relationship between temperature and FDP in strawberry appear to be based mostly on anecdotal evidence, not planned studies. Darrow (1966) states that at the beginning of the strawberry season in Maryland, the average period from flower opening to berry maturity is about 31 d, and at midseason, with longer days and higher temperatures, 5 to 6 d less.

The primary objective of the research described in this paper was to determine FDPs for strawberry grown in a winter, annual hill production system. The effect of flower position (i.e., primary, secondary, or tertiary) on FDP, and the relationship between FDP and post bloom air temperature, were also investigated.

Materials and Methods

Plants of 3 strawberry cultivars (Camarosa, Joy, and Sweet Charlie) were grown in a raised bed, annual hill production system at the Maroochy Research Station in Nambour, Queensland (26° S latitude) during the 2000 production season. Generally, in west central Florida and southeastern Queensland, 'Sweet Charlie' (a University of Florida cultivar) produces relatively high early season yields; 'Joy' (a Department of Primary Industries and Fisheries Queensland cultivar) produces high mid season yields; and 'Camarosa' (a University of California cultivar) produces high late season yields. Flowers from each cultivar were tagged when available from 15 June (equivalent to 15 Dec. in the northern hemisphere) to 17 Aug. (equivalent to 17 Feb. in the northern hemisphere). In total, 268 randomly chosen, open flowers were tagged (105 'Camarosa, 82 'Joy', and 81 'Sweet Charlie'). Flowers on 'Camarosa' were tagged on six dates (15, 28 June; 21, 28, 31 July; and 17 Aug.), 'Joy' on five dates (27, 28 June; 21, 28 July; and 17 Aug.), and 'Sweet Charlie' on five dates (15, 28 June; 21, 28 July; and 15 Aug.). The number of flowers tagged ranged between 3 and 32 for each cultivar on a particular date. On each tag, the date and flower position (1°, 2°, or 3°) was recorded. Then, as fruit approached horticultural maturity, they were observed every day and the dates on which they reached full maturity (i.e., full color) were recorded. This data was used to calculate FDP. Fruit were harvested after reaching full maturity. (Non-tagged, ripe fruit were harvested from plants twice a week.)

An analysis of covariance model (SPSS statistical software package) was used to examine the effect of categorical variables *cultivar* and *flower position* on FDP, and the relationship between FDP and mean air temperature of 1 to 4 week post bloom intervals. The final model includes only categorical effects that had a statistically significant effect on FDP and the mean temperature for the post bloom interval that best explained variation in FDP.

Results and Discussion

FDP ranged from 24 to 35 d for 'Sweet Charlie', 27 to 38 d for Camarosa', and 28 to 44 d for 'Joy'. These ranges are well within the range of 20 to 50 d reported for strawberries in general (Galletta and Bringhurst, 1990).

The model used for the final analysis of covariance (Table 1) is given by the equation FDP = 66.613 + $\tau_{cultivar}$ - 2.2 × mean 4-week post bloom air temperature. Mean daily air temperature was calculated for the 4-week period after a flower was tagged and also for 1- to 3-week windows within the 4-week period. Mean temperature for the entire 4-week period accounted for more variation in FDP than the mean temperature for shorter lengths of time, and therefore was included in the final model. The parameter $\tau_{cultivar}$ is equal to the effect of individual cultivars on the overall mean FDP at a given temperature. Relative to this mean, 'Sweet Charlie' fruit ripened 2.8 d sooner, 'Camarosa' fruit 0.5 d later, and 'Joy' fruit 2.3 d later. These effects on FDP were all significantly different from one another (Table 2). The slope parameter, -2.2, indicates that for every 1 °C increase in mean post bloom air temperature, FDP decreases 2.2 d on average (Fig. 1). Both cultivar and mean 4-week air temperature account for a significant proportion of the total variability in FDP (Table 1). The R^2 for the overall model is 0.60, with 40% of the variability attributable to unknown variables. In other models, not re-

Table 1. Analysis of covariance for fruit development period (FDP).

Source of variation	Type III sum of squares	df	Mean square	F	P
Air temp	804.4	1	804.4	171.045	<0.001
Cultivar	1094.6	2	547.3	116.376	<0.001
Residual error	1241.5	264	4.7		
Total	3124.5	267			

Table 2. Effect of cultivar on fruit development period (FDP).

Cultivar	Effect on FDP (days)[z]
Sweet Charlie	-2.8 a
Camarosa	0.5 b
Joy	2.3 c

[z]Numbers expressed as effect of cultivar relative to the mean for all cultivars. Numbers followed by different letters are significantly different as determined by multiple contrasts ($P \leq .05$, adjusted for multiple comparisons using the Bonferroni joint estimation procedure).

ported in this paper, no significant cultivar × post bloom air temperature interactions were observed, and flower position did not have a significant effect on FDP.

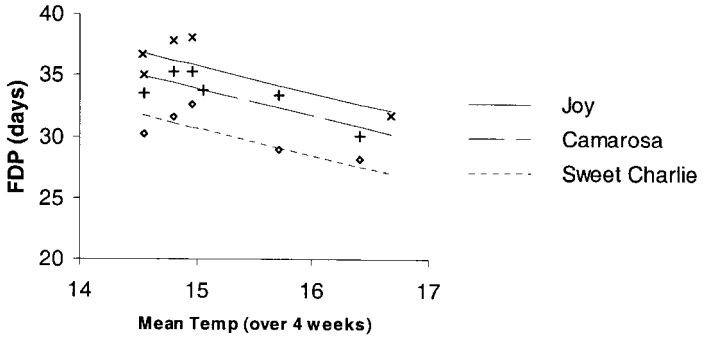

Fig. 1. Linear relationship between fruit development period (FDP) and 4-week post bloom mean air temperature (°C) for three strawberry cultivars. To reduce the complexity of the graph, only the mean FDP is reported for each of the 5 ('Joy' and 'Sweet Charlie') or 6 ('Camarosa') dates that flowers were tagged.

Information gained from this study should help us achieve our ultimate goal, which is to develop a dependable crop forecasting system. The fact that there is a significant difference in FDP among cultivars indicates that we will have to estimate a unique set of FDP parameters for each cultivar grown. To obtain reliable estimates will require that mean post bloom air temperature and possible other variables be taken into account.

Using 'Sweet Charlie' as an example we can see how the model described above might be used in practice. A 'Sweet Charlie' flower open on 1 Feb. should, on average, develop into a mature fruit in 28.0 d. A 'Sweet Charlie' flower open on 1 Mar. should, on average, develop into a mature fruit in 22.6 d (i.e., 5.4 d less than the fruit ripening in February). These estimates are based on 61-year mean air temperatures for February and March of 16.3 °C and 18.7 °C respectively (Albregts et al., 1990).

Literature Cited

Albregts, E. E., C. M. Howard, and C. K. Chandler. 1990. 1990. Climatological report and historical information from 1929-1990. Dover AREC Research Report DOV-1990-1.

Darrow, G. M. 1966. The strawberry. Holt, Rinehart and Winston, New York.

Galletta, G. J. and R. S. Bringhurst. 1990. Strawberry management, p. 83-156. In: G. J. Galletta and D. G. Himelrick (eds.), Small fruit crop management. Prentice Hall, Englewood Cliffs, NJ.

Galletta, G. J. and D. G. Himelrick. 1990. Small fruit crop management. Prentice Hall, Englewood Cliffs, NJ.

Hancock, J. F. 1999. Strawberries. CABI Publishing, Wallingford, U.K.

Westwood, M. N. 1978. Temperate-zone pomology. W.H. Freeman and Company, San Francisco.

Wilson W. F. and M. J. Giamalva. 1954. Days from bloom to harvest of Louisiana strawberries. Proc. Amer. Soc. Hort. Sci. 63:201-204.