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Optimal Harvest Date Equations for West Virginia Apples

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Abstract. **This report presents optimal harvest data equations (OHDE) calculated for 6 cultivars for apples at 3 locations in eastern West Virginia. In general, the equations predicted the observed harvest date one day better than the technique of using average calendar days for fruit development. The equations also indicated that bloom date was more important for determining the harvest date than the mean temperature during the growing season. Nonetheless, because of variability between equations, the overall usefulness of using the historical approach to the development of OHDE is limited.**

Optimal Harvest Date Equations (OHDE) for apples and other fruit have been developed because they are simple and inexpensive predictive tools. Two factors, however, make it difficult to develop these equations. First, about 10 years are required to collect appropriate data on temperature and the dates of full bloom and optimal harvest. Second, the equations are not universal. Separate equations must be derived for individual cultivars and climatic regimes. The purpose of the work reported here was to test the feasibility of using existing records of temperature and bloom and harvest dates in calculating OHDE. If successful, this technique would reduce the effort required to develop these effective predictive tools.

Baker and Brooks (1) suggested that the bloom date and temperature during the growth season could be used to predict fruit maturity. Based on this premise, a number of investigators (2, 3, 4, 5) have developed OHDE for apples to provide advanced information on optimal harvest dates without the necessity of analyzing some key feature of the fruit itself.

The 3 major factors in developing the OHDE are: 1) the average growth period for a given cultivar of apple, 2) the full bloom date (FB), and 3) the mean temperature (T) during a critical period of fruit development. Other factors such as position on the tree, moisture, biological stress, and growth regulators also may play a role in fruit development but were not considered in developing these models.

In general, the form of the OHDE developed by Luton and Hamer (5) is HD = BO + (B1 × FB) + (B2 × T), where HD = harvest date, BO = average growth period for a particular cultivar, and B1 and B2 are coefficients describing the influences of FB and T on fruit development.

The values for BO, B1, and B2 are determined by performing a stepwise linear regression. In the Luton and Hamer model, the values are 68.1, 0.243, and 3.52, respectively. The accuracy or goodness of fit of this equation is described by the coefficient of multiple determination (R^2). Previous workers developed OHDE by collecting fruit from a series of dates before and after the anticipated optimal harvest date. Following a period of storage, fruit were removed and evaluated for overall quality. Thus, an optimal harvest date was determined.

The accuracy of an OHDE is no better than the quality of data used to produce it. We appreciate that the data used here are imperfect. For example, differences in temperature between the weather station and the orchard exists, as well as differences in what various workers report as full bloom. Factors such

Table 1. Average bloom and harvest dates for 6 apple cultivars from 3 locations in West Virginia.

Cultivar	Orchard	Average bloom (Julian day)	Average harvest (Julian day)	Growth period (days)
Jonathan	A[z]	117	262	145
	B	120	264	144
	C	114	253	139
Golden Delicious	A	117	268	151
	B	123	260	137
	C	117	257	140
Delicious	A	117	270	153
	B	120	274	154
	C	115	257	142
York	A	119	285	166
	B	123	290	167
	C	118	283	165
Rome	A	121	296	175
	B	124	291	167
	C	118	280	162
Stayman	A	119	285	166
	B	120	299	179
	C	116	291	175

[z]A = 13 years, Twin Ridge Orchards; B = 10 years, Grand View Orchards; C = 7 years, Consolidated Orchards.

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Table 2. Summary of coefficients of multiple determination (R^2) between apple harvest date (HD), full bloom date (FB), and the mean temperatures in °F for June, July, and August (T). HD = BO + (B1 × FB) + (B2 × T).

Cultivar	Orchard[z]	Coef. (R^2)	Var. Const. (BO)	FB Const. (B1)	T Const. (B2)	Harvest predictions O − C ± SD[y]	O − P ± SD[x]
Jonathan	A	0.392	262	0.407	−0.688	4.2 ± 2.9	3.7 ± 1.6
	B	0.402	153	0.317	1.017	3.9 ± 3.9	3.5 ± 2.4
	C	0.527	153	0.646	0.358	5.1 ± 2.7	3.6 ± 1.8
Golden Delicious	A	0.066	197	−0.198	1.348	8.1 ± 6.8	8.2 ± 6.0
	B	0.498	139	0.216	1.324	2.8 ± 2.7	2.0 ± 1.9
	C	0.466	115	0.629	0.993	5.7 ± 3.4	3.1 ± 3.3
Delicious	A	0.064	283	0.159	−0.456	4.8 ± 3.7	4.6 ± 3.7
	B	0.356	153	0.249	1.271	4.4 ± 2.4	3.3 ± 2.4
	C	0.383	146	0.499	0.743	4.4 ± 2.7	3.1 ± 2.9
York	A	0.181	371	0.201	−1.580	6.0 ± 4.4	6.1 ± 2.9
	B	0.102	176	0.079	1.561	5.6 ± 5.0	6.0 ± 3.8
	C	0.901	−6	1.460	1.669	6.8 ± 5.8	2.4 ± 1.4
Rome	A	0.347	65	0.345	2.669	4.6 ± 3.2	4.0 ± 2.3
	B	0.648	134	0.172	1.895	4.0 ± 1.4	1.7 ± 1.8
	C	0.738	−6	0.997	2.356	5.3 ± 4.8	3.1 ± 1.8
Stayman	A	0.047	379	−0.14	−1.081	5.8 ± 5.5	5.1 ± 4.5
	B	0.539	141	0.139	1.966	3.8 ± 2.6	2.8 ± 2.4
	C	0.458	50	0.682	2.309	6.6 ± 3.2	4.4 ± 2.6
Average		0.395	113	0.381	0.982	4.8	3.5

[z]See Table 1.
[y]O − C = the difference in days between the observed and average calendar harvest date.
[x]O − P = the differnce in days between the observed and predicted harvest dates.

as market, labor, weather, and tradition also influence harvest dates. The purpose of this study, however, was to determine the feasibility of using existing data rather than collecting new data in the development of OHDE.

The harvest date used here is the first date on which a particular cultivar of fruit was harvested. Full bloom dates were obtained from the W.V. Univ. Expt. Sta. at Kearneysville and from orchards B and C (Table 1). Mean temperatures (°F) for May, June, July, and August were obtained from the Univ. Expt. Sta. at Kearneysville and the National Climate Center, Ashville, N.C. Fahrenheit was used in this study because temperature data are normally available to growers in this form. The dates shown are Julian calendar days. A stepwise linear regression was run to establish the coefficients used in the OHDE for the West Virginia orchards.

Table 1 summarizes full bloom and harvest data from 3 orchards in eastern West Virginia. The cultivars shown are listed in the order of days required to produce commercially mature fruit.

As shown in Table 2, the average coefficient of multiple determination (R^2) increased to 0.4 when both full bloom data and temperature were used to develop the harvest date equation. We observed that a third of the equations had an R^2 value in the range of 0.5 to 0.8, which is equivalent to that obtained by earlier workers.

The simplest equation for predicting a harvest date is one based upon an average growing season. The value shown in Table 2 for O − C is the difference between the observed growing season and the average growth season based upon calendar days. The calendar days were calculated as the average number of days between full bloom and harvest. The average value of O − C in this study was 4.8 days. The use of OHDE improved the ability to predict the observed harvest date by about 1 day. The column labeled O − P is the difference between the observed growth season and the one predicted by the OHDE equation. The average difference was 3.5 days.

OHDE developed from existing temperature and bloom, and harvest date records can provide useful information on the effect of bloom date and growing season temperatures on fruit maturity. For example, we concluded from this study that, for eastern West Virginia, a 3-day delay in full bloom or a 1°F rise of mean temperature during June, July, and August delayed fruit harvest by 1 day. We also observed that when compared to a model based solely on calendar date, OHDE improved the prediction of harvest dates by 1 day. In general, OHDE calculated by historical data appear to be less precise than those developed by a careful estimation of optimal harvest dates. In the final analysis, the use of OHDE may be limited to a general indication of harvest dates. The harvest dates for fruit destined for long-term storage, when appropriate maturity is most critical, may have to be determined by some physiological parameter such as respiration (6) or ethylene production (2).

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