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Quantifying relations of preharvest temperature, light, and precipitation with superficial scald development on apple (Malus domestica Borkh.).

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QUANTIFYING RELATIONS OF PREHARVEST TEMPERATURE, LIGHT, AND PRECIPITATION WITH SUPERFICIAL SCALD DEVELOPMENT ON APPLE (*MALUS DOMESTICA* BORKH.)

A Dissertation Presented

by

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ABSTRACT

QUANTIFYING RELATIONS OF PREHARVEST TEMPERATURE, LIGHT,

AND PRECIPITATION WITH SUPERFICIAL SCALD DEVELOPMENT

ON APPLE (MALUS DOMESTICA BORKH.)

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Superficial scald of apples (scald) is a physiological disorder of apples, usually appearing following cold storage of fruit. Susceptibility to the disorder is largely a function of preharvest climatic conditions and fruit maturity for susceptible cultivars. To facilitate management decisions, it would be useful to be able to predict potential scald severity at harvest. It was the purpose of this study to attempt to identify and quantify preharvest conditions which result in fruit being especially scald susceptible or especially scald resistant.

Data were solicited worldwide from researchers who had been studying scald. Information solicited included percent of fruit scalding after 1 week in room temperature air following 20 weeks air storage at 0C, as well as preharvest temperature, rainfall, and light conditions, and fruit maturity at harvest measured by a starch-iodine test. Cultivars included in the study were 'Cortland', 'Delicious', and 'Granny Smith'.

Ordinary Least Squares (OLS) regression equations were developed separately for each cultivar to establish relationships between variables representing preharvest conditions and amount of scald development on fruit. All data were used to generate OLS equations relating scald development to selected variables, and where coefficients were statistically significant, some consistent results

were observed. Higher mean temperatures during the preharvest period and very high temperatures (≥25C or 30C) in the week immediately preceding harvest were associated with increased scald development. Later harvest, higher starch score (riper fruit), more rainfall, more light, and more preharvest days with cool temperatures (≤6C, 8C, 10C or 12C) were associated with reduced scald development. Results were consistent among cultivars.

Logit equations were developed to separate especially scald-susceptible fruit and especially scald-resistant fruit from other fruit. Separate equations were created within fruit growing areas and cultivars. When lots of fruit were divided into two categories, ones containing with more than ("Bad") and less than 60% of fruit developing scald, respectively, equations correctly placed 80-% of lots. When the two categories were defined as lots in which more than or fewer than 20% ("Good"), respectively of fruit developed scald, equations correctly placed 76-94% of samples. Importance of factors determining these differences in scald susceptibility varied among locations and cultivars.

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CHAPTER I

INTRODUCTION

Superficial scald (scald) is a physiological disorder of apples and pears. It is observed as a necrotic browning of the fruit peel, and normally appears only after fruit have been removed from cold storage. Incidence of this disorder is quite variable from year to year, among cultivars, and among fruit growing regions. It is generally more severe on early harvested fruit, while other disorders, such as senescent breakdown, fruit softening, and decay, are more prevalent on late harvested fruit. It would be useful to know at harvest just how severe poststorage scald was likely to be in order to balance potential fruit losses due to scald development against potential losses from senescent breakdown, soft fruit, and decay. Assessment of preharvest weather conditions may prove useful for this purpose.

Preharvest weather conditions and fruit maturity at harvest have repeatedly been correlated to poststorage scald development. Appropriate quantification of these effects could make possible develpment of a model describing their effects on scald development and ultimately lead to predicting scald susceptibility at time of harvest. To create a quantitative model showing how preharvest weather and at-harvest fruit maturity relate to scald development, quantitative measurements of these factors must be made. In choosing measurement methods, a number of considerations must be taken into account. First, the factor, as measured, must relate to scald development. Second, the measurement must be taken in such a way that results will be consistent when taken by a variety of people in different places. Third, a measurement taken from a single location must suffice for a large enough area of orchard that the measurement will be useful in terms of both time and expense of collecting, and in relation to scald development. Orchard blocks, even very small ones, will show some variation in temperature, light penetration, and fruit maturity at a given time. It must be assumed that these differences may be disregarded in a model developed to explain differences in scald development within that block.

The primary objective of this project is to relate quantitatively post-storage scald development to preharvest weather conditions and fruit maturity at harvest. A second objective is to generate models using information available at harvest to predict poststorage scald incidence. In order to best achieve these objectives a large and varied data set is needed. Therefore, data have been solicited from researchers who have been studying scald development in some of the major apple growing areas of the world. This solicitation has resulted in a large and varied set of data. Because the data were, in most cases, collected prior to the initiation of this study, the specific measurements were not the same in all cases. Because of the impossibility of collecting measurements of all parameters desired in every location when using previously collected data from a wide variety of sources, the data must be broken apart according to what is available from where. Worldwide, 1186 cases with information relating to scald incidence on 'Delicious' were available. Because more data were available for 'Delicious' than for other cultivars, the main focus of the study is scald development on 'Delicious'. Other cultivars, notably 'Granny Smith' (347 cases from New Zealand and South Africa) and 'Cortland' (344 cases from the Horticulture Research Center, Belchertown, MA), were also available for the study.

CHAPTER II

LITERATURE REVIEW

Superficial Scald Defined

The physiological disorder of pome fruits, superficial scald, commonly known as "scald", occurs frequently among cold-stored fruit (Porritt, et al., 1982). It appears initially as a browning (necrosis) of the peel, and in more severe cases the flesh directly beneath the affected peel also exhibits browning. The disorder usually becomes visible only after fruit have been stored at low temperature continuously for three months or more and then placed in room temperature air for a few days.

Biochemical Causes of Scald

The biochemical cause or causes of scald are not well understood. Brooks, et al. in 1923 published results of studies showing that when fruit were well ventilated during storage, poststorage scald incidence was reduced, and concluded that the value of the resulting aeration was that scald-causing volatiles were removed. In 1948 Smock and Southwick reported on methods of air purification designed to remove "scald gases", unknown volatiles which, if present, would cause scald to develop. However, Smock (1961) later found that rapid air exchange did not control scald, and that air purification using activated carbon only sometimes decreased scald. Huelin and Kennett (1958) studied the roles of a number of volatiles, acids, alcohols, esters, aldehydes, ketones, and hydrocarbons in scald development, and concluded that none were directly concerned in scald development. Currently, there are a number of hypotheses which seek to explain the variability in susceptibility of fruits to scald. The primary focus of recent research has revolved around the observation that alpha-farnesene and its oxidation products, conjugated trienes (CT), are correlated to scald development (Huelin and Coggiola, 1970a, b, c). Meir and

Bramlage (1988), however, found only a weak relationship between scald incidence and CT or alpha-farnesene concentration, and postulated that scald-reducing antioxidant activity as measured by differences in OD200 of hexane extracts of fruit may be a reliable indicator of scald susceptibility. They also observed that the various OD peaks in hexane extracts, possibly representing different conjugated trienes, correlated in varying degrees to scald development. Du and Bramlage (1993) have proposed that it may not be CT281, the most commonly measured group of conjugated trienes and the ones usually related to scald development, but rather a metabolite or catabolite of that substance which may be responsible for scald development. In any case the reasons for variation in scald susceptibility of fruit are not well understood at present.

While the actual cause of scald remains elusive, a great deal of research has been done in the area of defining some of the situations and conditions which lead to greater or lesser scald susceptibility and development.

Scald and Cultivar

Certain cultivars are very susceptible to scald, while others are essentially immune to the disorder. Some susceptible cultivars which have been studied are 'Stayman' (Merritt, et al. 1961), 'Delicious' (Blanpied, et al. 1991; Ingle and D'Souza 1989), 'Edward VII' (Fidler 1957), 'Granny Smith' (Little and Taylor 1981; Little and Barrand 1989), and 'Cortland' (Barden, 1992). Since cultivars vary in scald susceptibility, they may vary in response to the environmental conditions which influence scald. Comparisons of these possible cultivar-to-cultivar differences generally have not been made.

Within cultivars there also may be differences in scald susceptibility. Ingle and D'Souza (1989) measured scald on five strains of 'Delicious', and while they were not able directly to compare strains with respect to scald susceptibility because of differences in tree age, rootstock, and growing site, it appeared that there may have been strain related differences in susceptibility. Autio (1991) reported rootstock related differences in scald susceptibility in 'Starkspur Supreme Delicious'. It was not clear if these differences were directly caused by rootstock, or if rootstock-induced differences in time of fruit ripening and thus differences in fruit ripeness at harvest actually caused the differences in scald susceptibility.

Scald and Fruit Location Within Tree

Another tree-related influence on scald susceptibility is fruit location within the tree. Meir and Bramlage (1988) measured both number of scalded fruit and poststorage scald severity on fruit harvested from the interior and exterior of 'Cortland' grown on seedling rootstocks. They found that of fruit harvested on a given date, more of the fruit from the exterior than from th interior of the trees developed scald after 20 weeks at 0°C followed by 7 days at 20°C, but that the scald on the fruit from the interiors of the trees was the more severe. They also found that within a given harvest date, fruit from the interior of a tree were less mature, had less red color, and had lower soluble solids. While fruit from the exterior of the trees ripened during the course of the experiment, fruit from the interior did not ripen measurably. However, scald development on stored fruit from the interior of the tree declined significantly over the 19-day harvest period.

Scald and Fruit Maturity

The results of Meir and Bramlage (1988) showing a decrease in scald unaccompanied by ripening are not typical. Barden and Bramlage (1994) showed that advancing fruit ripening reduced scald development on 'Cortland'apples. In general it has been reported that as fruit mature they become less susceptible to poststorage scald development. Brooks, et al. (1919a) reported decreases in poststorage scald when fruit were harvested when "well colored" ('Rome Beauty', 'Stayman' 'Winesap', and 'Baldwin') or "rather overripe" ('Bellflower', 'Grimes'). Morris reported a negative correlation between soluble solids, a more objective measure of maturity than those used by Brooks, and poststorage scald development on New Jersey-grown 'Stayman' apples. In the 1980's the starch iodine test as a measure of fruit maturity came into use. This test (Priest and Lougheed, 1988) measures the extent of conversion of starch to sugar. Watkins, et al. (1982) in a study of New Zealand-grown 'Granny Smith' apples found a reduction in the incidence of scald as the starch index increased. Blanpied et al. (1991) confirmed this relationship in 'Starkrimson Delicious' grown at research stations throughout Canada and the USA. Harvest date as days after full bloom (DAFB) can also be used as a measure of fruit maturity. Ingle and D'Souza (1989) concluded from a study of several strains of 'Delicious' grown in West Virginia that DAFB was a better predictor of poststorage scald than were fruit firmness or starch score.

Scald and Climate

Much has been published regarding climatic effects on scald development. Primary areas of climatic influence which have been cited are temperature, light, precipitation, and their interactions.

Low Temperature

It has been well established that scald susceptibility tends to be less when low temperatures have occurred in the orchard before fruit are harvested. Fidler (1957) observed that lower temperatures in the six weeks prior to harvest resulted in reduced scald development in 'Edward VII' grown in England. Various temperatures have been proposed as those below which fruit may have some protection from scald development. Working with 'Stayman' apples in New Jersey, Merritt et al. (1961) proposed that 50°F (10°C) was the orchard temperature below which some protection from scald development may be initiated. Morris (1964), also working in New Jersey, found that preharvest hours below 12.8°C correlated better than hours below 10°C with scald development in 'Stayman' and 'Rome Beauty' apples.

Blanpied et al. (1991), working with 'Starking Delicious' grown in seven different areas in North America, observed a high correlation between preharvest hours below 10°C and scald development. Bramlage and Watkins (1994), however, found that while hours below 10°C correlated well with postharvest scald development on 'Cortland' and 'Delicious' grown in Massachusetts (one of the areas in the above-mentioned study by Blanpied, et al. (1991) that relationship did not exist for 'Granny Smith' or 'Delicious' from most areas of New Zealand. They suggested that since temperatures drop quite sharply to 10C in the northeastern US, whereas the climate of New Zealand is more moderated, scald may actually become inhibited following temperatures higher than the North American data indicate. Their data from New Zealand are consistent with this theory.

Also, more than a simple temperature cutoff may be in effect, i.e. very low temperatures may have a greater effect than moderately low temperatures. This question has not been explored previously.

High Temperature

There is evidence that subsequent high temperatures may cancel the effect of low temperatures (Merritt et al., 1961). However, there is no indication of how high those temperatures must be, and of what duration. Uota (1951), using temperature-controlled caged trees found that 100% of 'McIntosh' fruit from the "high" temperature tree developed poststorage scald, while 65% and 2% of fruit from the "medium" and "low" temperature trees, respectively developed scald. The temperature ranges in the "high", "medium", and "low" temperature cages ranged from 21-33°C, 16-37°C, and 5-22°C, respectively.

Light

Light duration and intensity also have been shown to influence scald development. Fidler (1957) reported that increasing hours of sunshine during the six weeks preceding harvest correlated positively with scald development on 'Edward VII' apples. Smock (1953) reported higher incidence of scald on 'Rhode Island Greening' and 'McIntosh' when temperatures were high during the six weeks before harvest. Because high temperatures generally are accompanied by bright sunshine and lack of rain, it is not clear which of these factors is most influential in determining scald development. Barden and Bramlage (1994) found that bagging fruit with brown kraft paper bags, and thus eliminating almost all light, increased scald susceptibility of 'Cortland' apples. This type of experiment eliminates effects of temperature and precipitation on scald development, but also creates a situation in which light is substantially less than it normally would be in an orchard. How much year-to-year differences in light conditions might affect scald development in fruit grown at a given location is unknown. It is possible that the widely varying light conditions found in different apple growing areas of the world may be responsible for some of the variation in scald susceptibility. Whether or not light and temperature effects can be separated is not known.

<u>Rainfall</u>

Work reported by Brooks (1919b) showed that heavily-irrigated fruit tended to develop more scald than did lightly irrigated-fruit. The timing of the irrigation was not mentioned. The data of Loetter, et al. (1985) showed that fruit heavily irrigated early in the season were less susceptible to scald than were fruit which received less water. In contrast, fruit which were heavily irrigated late in the growing season were more susceptible to scald than were other fruit. However, the observation that scald susceptibility tends to be greater in hot, dry seasons than in cool, wet seasons (Fidler, 1957) suggests that rainfall prior to harvest may decrease scald development, although this response could just as well be due to the lack of high temperatures. Water availability is necessarily more controlled in areas where irrigation provides a large percentage of the total available water. While the timing of irrigation was shown by Loetter et al. (1985) to be important, the situation is less clear in areas where natural rainfall provides water for an orchard. It might be that there is less scald following a rainy season because of the accompanying reduced light conditions. Fruit from heavily irrigated orchards may tend to scald a great deal because those orchards experienced more sunshine and higher temperatures than did the orchards whose water came from natural rainfall with accompanying overcast skies and cooler temperatures.

Predicting Scald Development

Fidler in 1957 suggested that any attempt at predicting poststorage scald development should be based on past experience at the farm at which the fruit were grown. He believed that year-to-year variation of scald within an orchard should be predictable based on rainfall and sunshine during the six weeks before harvest. In the 1960's, as computers became available, it became practical to create multiple regression equations relating poststorage scald development to preharvest factors. Morris (1964) explained up to 83% of variation in scald development in New Jersey-grown 'Rome Beauty' apples based on fruit color measurements, preharvest hours below 55°F, fruit firmness and soluble solids at harvest. He found that the most important factors were Tan^{-1}-a/b (a color score computed from the -a/b ratio) which, if increased, increased scald development, and preharvest hours below 55°F which, if increased, decreased scald development. All of Morris' equations were generated using linear models. Relationships between scald development and weather and maturity factors are not necessarily linear. Lau (1993) attempted to predict scald susceptibility in British Columbia-grown 'Delicious' using sigmoidal models in addition to linear models. He concluded that the best predictions were those based on sigmoidal models using functions of preharvest hours below 10°C and/or harvest starch score as variables, and creating a separate equation for each location studied.

CHAPTER III

MATERIALS AND METHODS

The Independent Variables

The preharvest factors whose effects on poststorage scald development were studied are listed and described below.

Low Temperatures

Low temperatures were sometimes recorded as daily temperature minima and sometimes through hourly measurements. For modelling purposes the measurements used were number of days with temperatures dropping to or below 6, 8, 10, or 12°C between January 1 and the day before harvest in the southern hemisphere, or between August 2 or 3 and the day before harvest in the northern hemisphere. Where hourly temperature recordings were available, number of hours of preharvest temperatures at or below 6, 8, 10, or 12°C during the above-mentioned time periods was also used. Initially, hours at or below 14°C were also included, but since temperatures that cool are common throughout the summer months in all measured locations, it was not at all clear when it would be reasonable to start counting. Therefore, this variable was abandoned. Additional variables were created with adjustments made to account for possible reductions in effect of cool temperatures if they were followed by temperatures of 30°C or greater.

The low temperature variables used throughout this study are: D6, D8, D10, and D12 where Dx refers to the number of preharvest days in which the temperature was measured at or below x°C, D6D, D8D, D10D, and D12D where DxD refers to the number of preharvest days in which the temperature was measured at or below x°C, with the count restarting at zero when a temperature at or exceeding 30°C was reached, D6H, D8H, D10H, and D12H where DxH refers to the number of preharvest days in which the temperature was measured at or below x°C, with the count reduced by one for each preharvest day in which the temperature reached or exceeded 30°C, and D6HH, D8HH, D10HH, and D12HH which are similar to the DxH's except that the day count is reduced by 2 rather than 1 for each 30°C day. These four variable types, Dx, DxD, DxH, and DxHH were calculated as hours, rather than days at or below x°C, with 1 or 2 hours, rather than 1 or 2 days being subtracted in the last two variables. These variables were labelled, H6, H8, H10, H12, H6D, H8D, H10D, H12D, H6H, H8H, H10H, H12H, H6HH, H8HH, H10HH, H12HH.

High Temperatures

High temperatures were recorded in the same manner, and over the same time period, as low temperatures. Variables created were number of days or hours with temperatures at or above 30, 28, or 25°C. These variables showed if it was very hot in the late summer before harvest. Days or hours at or above 30, 28, or 25°C during the seven days prior to harvest were used to indicate if a fleeting high temperature effect on scald could be detected. Because most high temperatures are recorded early, during the recorded preharvest time, the number of days or hours at or above 30, 28, or 25°C may be the same for all harvests in a given season. Therefore, these high temperature variables may be useful primarily to explain season-to-season differences in scald development. The high temperature variables are D30, D28, D25, H30, H28, and H25, which are, respectively, number of preharvest days with temperatures at or above 30, 28, and 25°C and number of preharvest hours of temperatures at or above 30, 28, and 25°C. Note that a high temperature component is included in a number of the low temperature variables above.

Fruit Maturity

Fruit maturity was measured at harvest using a starch test (Priest and Lougheed (1988), Blanpied and Silsby (1992)). As apples mature and ripen, starch is converted to sugar, and this loss of starch is measured as a number from 1 to 8, with 1 indicating the most starchy, least ripe fruit, and 8 indicating the least starchy, ripest fruit. The variable, ST, which is the starch score has been used throughout this study.

Rainfall

Rainfall measurements were blocked by time period since reports in the literature suggest that rainfall at different times may have different effects on scald susceptibility (Lötter et al. (1985) and Little and Barrand (1985)). Thus variables were created to show effects of rainfall during various preharvest periods. Specific dates at which one would start measuring rainfall are naturally different in the northern vs southern hemisphere. Preliminary examination of harvest dates from the northern vs southern hemispheres indicated that shifting dates seven months rather than six would be most appropriate. Hence February in the southern hemisphere is considered equivalent to September in the northern hemisphere. Rainfall categories used were 1)average daily rainfall in mm from 1 February in the southern hemisphere or 2 or 3 September in the northern hemisphere until harvest (RAIN246), 2)average daily rainfall in mm from 22 January in the southern hemisphere or 23 or 24 August in the northern hemisphere until harvest (RAIN236) and 3)average daily rainfall in mm during the three weeks prior to harvest (RAIN3WK). In addition July/December (north/south) rainfall (JRAIN) and August/January (north/south) rainfall (ARAIN) were recorded to see how these contributed to year-to-year differences in scald susceptibility. The reason for including both RAIN246 and RAIN236 is that while RAIN246 takes over where ARAIN leaves off, harvests were accasionally made between day 236 and day 246, so the RAIN236 variable would be available, but the RAIN246 variable would be meaningless.

Light

Light measurements were available from a few sources. Accumulated MegaJoules/m^2 light was measured daily at the Elgin location in South Africa, daily hours of sunshine were measured at the Nova Scotia, Canada site, and a subjective comment was recorded daily at the US Weather Bureau at Quabbin Reservoir near the Massachusetts, USA site. These qualitative reports from Quabbin included such notations as "rainy", "cloudy", "partly cloudy", "fair" and were assigned values as follow: 0 = nothing more favorable than "cloudy" for the day, 1 = "fair" for the entire day, and 0.5 = everything in between. As in the case of timing if rainfall, it was not clear during which period(s) of time varying light would most influence scald susceptibility. Thus three variables including different time frames were generated. Light variables were average daily light as measured for the week preceding harvest (SUN1WK), average daily light measured from 1 February in South Africa or from 2 or 3 September in North America until harvest(SUN246), or average daily light measured from 22 January in South Africa or from 23 or 24 August in North America (SUN236).

Statistical Analyses

The primary statistical tool used for analysis of the data was ordinary least squares analysis (OLS). Since OLS has been proven to be the best linear unbiased estimator, it is a good point from which to start. Both descriptive and predictive models for relating preharvest factors to development of poststorage superficial scald were developed. Because the relationship between the various independent variables and scald is unlikely to be linear, at least not over the entire range of values, several transformations of the data were assessed as to effectiveness in describing scald variability.

Transformations

Transformations of data can allow a non-linear function to be written in linear form so as to be used in an Ordinary Least Squares equation. For example, if it is hypothesized that Y is a function of ln(P), then a variable, X, defined as ln(P), can be substituted for the P variable, and the hypothesis that $Y = B_0 + (B_1 * X)$ may be tested. The Y variable, as well as X variables may be transformed.

For this project a number of transformations of both X and Y variables were used.

Exponential transformations. e^x where $0 \le x \le 1$ increases the the magnitude of difference in numbers near 1 relative to the difference in numbers near 0. Thus, transforming %scald to $e^{(\%scald/100)}$ might improve the fit of a linear equation relating starch score to scald development if, for example, there is little reduction in scald development as starch score rises from 1 to 4, followed by a rapid reduction in scald after starch score reaches 5. Transforming the X, scald in this example, magnifies the effect of the scald transformation.

Even if the effect of a variable on scald is linear, the amount of scald which can develop is limited to 0-100%. Where the Y variable (scald) has a lower limit which is often reached, as is the case with scald development in this project, it may be useful to use the Tobit regression procedure which incorporates a lower limit for Y. If this is not done, negative, and therefore meaningless, predictions for scald will likely result when X values are very high (for X with negative coefficient) or low (for X with positive coefficient).

Logarithmic transformations. Because ln(0) is undefined, logarithmic transformations of scald percentages must be based on some function of percent scald which does not include the possibility of a variable being zero. Percent scald + 1, which results in values of 1 to 101, is a simply calculated function and has been used throughout this project. Logarithmic transformation could be useful in a situation in which scald increased as the value of a variable increased once a certain level of the variable was reached.

Tobit Regression Procedure

In some situations, especially among the 'Delicious' data, a great many fruit did not develop any scald. Where this situation occurred, the Tobit procedure (Tobin 1958) was used. Essentially, the Tobit procedure is an OLS analysis with the addition of a calculated limit beyond which the function is a constant; in this case the constant was defined as zero percent scald.

Predictive Models Using Probit and Logit Regression

In addition to these descriptive equations, other equations were developed in which lots of fruits were grouped to identify those lots of fruit which would be especially scald-susceptible and those lots which would be especially scald-resistant. Especially scald-susceptible fruit were defined as those from a lot of fruit in which over 60% would develop scald after storage. Especially scald-resistant fruit were defined as those from a lot of fruit in which fewer than 20% would scald after storage. Equations to identify fruit as belonging to one of two scald-susceptibility groups were developed using Probit or Logit regression (Maddala, 1983). In this procedure, the dependent variable is assigned a value of either zero or one. (In the first analysis here, lots of fruit in which over 60% of fruit developed scald were assigned a value of one, and all others were assigned a value of zero. For the second analysis, lots of fruit in which fewer than 20% of fruit developed scald were assigned a value of one, and all others were assigned a value of zero.) In both Probit and Logit models, an index, I, is created in which I ranges from minus infinity to plus infinity. This Index is then translated using a cumulative normal distribution (note this is nonlinear) to a range of 0-1. In the Probit model the index is generated as a linear function of the form Index (I)=XB. In the Logit model the dependent variable is first transformed using the function $Y = 1 / (1 + e^{(-XB)})$. A predicted value is assigned a value of zero if its Index is negative, or one if its Index is positive. Since the Index is a linear function of X, while the probabilities are not, all lots are placed in one or the other category (0 or 1) and probabilities beyond that were not considered.

Initial Investigations Using HRC Cortlands

Each year from 1985 to 1993, fruit were harvested from Cortland trees grown at the Horticulture Research Center (HRC) in Belchertown, MA. Some fruit were from trees grown on seedling rootstocks and some were from trees on M7 rootstocks. No distinction was made regarding this difference in fruit source. Each year a number of harvests were made and dates of harvest recorded. In most cases, fruit maturity was assessed at harvest using a starch-iodine test and the resulting color was rated against a chart (Priest and Lougheed, 1988). Ten fruit per bushel box were tested for starch (maturity). The remaining fruit were stored for approximately 20 weeks at 0°C, and then removed to room temperature air for seven days, after which each fruit was evaluated for the presence of scald. Scald was expressed as percent of fruit affected per bushel box. Temperature, light, and rainfall information were available as shown in Table 3.1. Information was compiled separately for each year.

Initial descriptive analyses were made to determine how much variability existed among the measured variables. Correlations among the "independent" variables were also calculated. Simple OLS regression equations were developed relating some of the "independent" variables to poststorage scald development. Chow's test (Chow, 1960) was used to determine if the relationship between scald and the independent variables was the same in different years.

Multiple regression equations were developed to see how much of the variability in scald development could be explained by the measured variables. Additionally, equations relating scald to a number of the independent variables were developed using a random sampling of about 85% of the available data. These equations were then applied to the remaining 15% of the samples, and the resulting "predictions" were compared to actual outcomes.

More regression equations were developed using variables created by treating the initially measured variables in a number of ways.

Data were transformed to their square roots or their natural logarithms. Low temperature variables were altered to reflect the possibility of influence of high temperatures following low temperatures. All of these various procedures were applied to the same set of data, thus introducing some bias into the systems of equations. Nonetheless, these newly developed equations were compared to the intial multiple regression equations, and the most promising treatments of the data, in terms of highest R^2 of developed equations, were selected for further use.

The final procedure applied to the data was Logit regression analysis (Maddala, 1983) which was used to identify lots of fruit which were especially resistant to scald development or which were especially susceptible to scald development. Equations were developed using a randomly selected 85% of the available data, and tested using the remaining 15% of the data. The form of the data used was that which appeared most promising based on comparisons of the previously developed equations.

Investigating Variation in Scald on HRC 'Delicious'

Conclusions formed based on the analysis were used to form the basis of the analysis of the much more extensive data sets relating to poststorage scald development in 'Delicious' and 'Granny Smith' apples, beginning with the Massachusetts (HRC) 'Delicious'.

Yearly means of scald development, fruit maturity at harvest, and harvest date were compared for HRC grown 'Cortland' and 'Delicious' fruit. Simple correlations between scald development and the various independent variables also were compared.

Scald on 'Delicious' Worldwide

Because it would be cumbersome to calculate all permutations of all variables at all locations, results from analyses of the HRC 'Delicious' were used as a guide in determining which variables to use for analyses of the worldwide 'Delicious' data.

Comparisons were made relating scald development in 'Delicious' to the factors potentially influencing scald development. Separate comparisons were made for lots of fruit coming from different locations worldwide.

Because not all factors were measured in all places at all times, a succession of models was developed, beginning with the one including the largest number of cases (and therefore the smallest number of variables), and ending with a model including the largest number of variables. Chow's tests were used to determine which groupings of variables were appropriate. Models were compared with reference to R^2 and to autocorrelation of error terms.

Components of the most effective models were used to create Logit equations to identify lots of fruit which would be especially scald susceptible and lots which would be especially scald-resistant.

Scald on 'Granny Smith'

The procedures applied to the 'Delicious' data also were applied to the 'Granny Smith' data.

Table 3.1 Data available for relating poststorage scald on 'Cortland', 'Rome', 'Stayman', and 'York' apples to selected preharvest factors.

CULTIVAR AREA	Year	N	Daily temperature		Starch	Rain	Light	Full bloom date
			Hourly	Minimum maximum				
CORTLAND								
MA[z]	1985	59	N	Y	N	Y	Y	Y
MA	1986	19	N	Y	N	Y	Y	Y
MA	1987	15	N	Y	Y	Y	Y	Y
MA	1988	26	Y	Y	Y	Y	Y	Y
MA	1989	22	N	Y	Y	Y	Y	Y
MA	1990	27	Y	Y	Y	Y	Y	Y
MA	1991	60	Y	Y	Y	Y	Y	Y
MA	1992	27	Y	Y	Y	Y	Y	Y
MA	1992	4	Y	Y	N	Y	Y	Y
NS[y]	1989	8	N	Y	Y	Y	Y	N
NS	1990	8	N	Y	Y	Y	Y	N
ROME								
WV[x]	1982	2	Y	Y	N	N	N	N
WV	1983	7	Y	Y	N	N	N	N
WV	1984	2	Y	Y	N	N	N	N
WV	1985	2	Y	Y	N	N	N	N
WV	1986	5	Y	Y	N	N	N	N
WV	1988	4	Y	Y	N	N	N	N
WV	1989	8	Y	Y	N	N	N	N
STAYMAN								
WV	1980	4	Y	Y	N	N	N	N
WV	1982	6	Y	Y	N	N	N	N
WV	1984	2	Y	Y	N	N	N	N
WV	1987	2	Y	Y	N	N	N	N
WV	1988	1	Y	Y	N	N	N	N
WV	1989	5	Y	Y	N	N	N	N
YORK								
WV	1984	2	Y	Y	N	N	N	N
WV	1985	1	Y	Y	N	N	N	N
WV	1987	4	Y	Y	N	N	N	N
WV	1988	4	Y	Y	N	N	N	N
WV	1989	4	Y	Y	N	N	N	N

[z] MA = USA, Massachusetts, Horticulture Research Center, Belchertown.
[y] NS = Canada, Nova Scotia.
[x] WV = USA, West Virginia.

Table 3.2 Cases available for relating poststorage scald on 'Delicious' apples to selected preharvest factors.

Area	Year	No.	Daily temperature		Starch score	Rain	Light	Full bloom date
			Hour-ly	Minimun maximum				
BC[z]	1990	75	Y	Y	Y	N	N	N
BC	1991	70	Y	Y	Y	N	N	N
BC	1992	68	Y	Y	Y	N	N	N
MA[z]	1986	8	N	Y	N	Y	Y	Y
MA	1987	60	N	Y	Y	Y	Y	Y
MA	1988	77	Y	Y	Y	Y	Y	Y
MA	1989	12	N	Y	Y	Y	Y	Y
MA	1990	24	Y	Y	Y	Y	Y	Y
MA	1991	45	Y	Y	Y	Y	Y	Y
MA	1992	15	Y	Y	Y	Y	Y	Y
MA	1992	9	Y	Y	N	Y	Y	Y
NZ5[x]	1987	3	N	Y	N	N	N	N
NZ5	1987	6	N	Y	Y	N	N	N
NZ5	1988	8	N	Y	Y	N	N	N
NZ5	1989	6	N	Y	Y	N	N	N
NZ5	1991	7	Y	Y	N	N	N	N
NZ6	1987	10	Y	Y	Y	N	N	N
NZ6	1988	9	Y	Y	Y	N	N	N
NZ6	1991	8	N	Y	N	N	N	N
NZ7	1987	9	Y	Y	Y	N	N	N
NZ8	1987	9	N	Y	Y	N	N	N
NZ8	1988	9	N	Y	Y	N	N	N
NZ8	1991	6	N	Y	N	N	N	N
SAHN	1986	24	Y	Y	N	Y	N	Y
SAHN	1987	24	Y	Y	N	Y	N	Y
SAHN	1988	24	Y	Y	N	Y	N	Y
SAEL	1980	60	Y	Y	Y	Y	Y	Y
SAEL	1981	75	Y	Y	Y	Y	Y	Y
SAEL	1982	40	Y	Y	Y	Y	Y	Y
SAEL	1982	40	Y	Y	N	Y	Y	Y
SAEL	1983	75	Y	Y	Y	Y	Y	Y
WV	82-89	38	Y	Y	N	N	N	N
WA*	1987	21	M	N	Y	N	N	Y
WA*	1988	13	M	N	Y	N	N	Y
WA*	1989	14	M	N	Y	N	N	Y
WA	1990	42	M	N	Y	N	N	Y
WA	1991	55	M	N	Y	N	N	Y

[z] BC = Canada, British Columbia, 15 orchards.
[y] MA = USA, Massachusetts, Horticulture Research Center, Belchertown.
[x] NZ5 = New Zealand, Hawkes Bay area.
[w] NZ6 = New Zealand, Nelson area.
[v] NZ7 = New Zealand, Canterbury area.
[u] NZ8 = New Zealand, Otago area.
[t] SAHN = South Africa, High Noon.
[s] SAEL = South Africa, Elgin.
[r] WV = USA, West Virginia.
[q] WA = USA, Washington.

Table 3.3 Data available for relating poststorage scald on 'Granny Smith' apples to selected preharvest factors.

Area	Year	No of cases	Temperature		Starch	Rain	Light	Full bloom date
			Hourly	Daily min./max.				
NZ3	1991	6	Y	Y	N	N	N	N
NZ4	1990	7	N	Y	Y	N	N	N
NZ4	1990	1	N	Y	N	N	N	N
NZ5	1987	10	N	Y	Y	N	N	N
NZ5	1988	10	N	Y	Y	N	N	N
NZ5	1989	10	N	Y	Y	N	N	N
NZ5	1990	7	N	Y	Y	N	N	N
NZ5	1991	8	Y	Y	N	N	N	N
NZ6	1988	9	Y	Y	Y	N	N	N
NZ6	1989	8	Y	Y	Y	N	N	N
NZ6	1990	8	Y	Y	Y	N	N	N
NZ6	1991	8	Y	Y	N	N	N	N
NZ7	1989	6	Y	Y	Y	N	N	N
NZ7	1990	7	Y	Y	Y	N	N	N
NZ7	1991	8	N	Y	N	N	N	N
NZ8	1989	5	N	Y	Y	N	N	N
NZ8	1990	5	N	Y	Y	N	N	N
NZ8	1991	6	N	Y	Y	N	N	N
SAEL	1980	15	Y	Y	Y	Y	Y	Y
SAEL	1981	40	Y	Y	Y	Y	Y	Y
SAEL	1982	30	Y	Y	Y	Y	Y	Y
SAEL	1983	40	Y	Y	Y	Y	Y	Y
SAEL	1991	35	Y	Y	Y	Y	Y	Y
SAHN	1986	24	Y	Y	N	Y	N	Y
SAHN	1987	24	Y	Y	N	Y	N	Y
SAHN	1988	24	Y	Y	N	Y	N	Y

[z] NZ3 = New Zealand, Auckland.
[y] NZ4 = New Zealand, Waikato area.
[x] NZ5 = New Zealand, Hawkes Bay area.
[w] NZ6 = New Zealand, Nelson area.
[v] NZ7 = New Zealand, Canterbury area.
[u] NZ8 = New Zealand, Otago area.
[t] SAEL = South Africa, Elgin.
[s] SAHN = South Africa, High Noon.

CHAPTER IV

RESULTS AND DISCUSSION, HRC 'CORTLAND'

Preharvest Factors Which May Affect Scald Susceptibility

When data for nine years (1985 through 1993) were assembled, correlations among time of harvest (measured as days after full bloom or as Julian date), harvest starch score, preharvest days with temperatures falling below 6, 8, 10, or 12°C, and poststorage scald incidence were calculated both across all years and separately within each of the nine years. In all years, harvest date, maturity (starch score), and preharvest days with temperatures falling to or below 6, 8, 10, or 12°C were negatively correlated with scald incidence (Table 4.1). Correlation coefficients varied by factor and from year to year, but in all individual years (except in the two places noted in Table 4.1), as well as in combined years, each factor was correlated with scald incidence with probability of at least 99%. However, all of these variables also were correlated with one another (Table 4.2). Table 4.3 is a correlation table similar to Table 4.2, but excluding starch score, for which only limited data were available. Here, also, the variables were correlated with one another. Because of these significant correlations, it is difficult to determine which factors directly influence scald susceptibility.

Creating Equations to Describe Scald Variation

Separate regression equations relating scald to each of the above-mentioned variables were made for each year, and equations were also made for the composite data. Table 4.4 shows results of comparing a simple series of equations. Equation A is the ordinary least squares regression equation relating poststorage scald incidence to harvest date. All 358 cases covering a period of nine years are included in the equation. Possible year-to-year differences in overall scald incidence and year-to-year differences in the influence of harvest date are not considered in Equation A; restraints are imposed so that the base rate for scald did not vary among different years, and that the influence of harvest date also was not different in different years. For Equation B, the first restraint is removed, and the base rate of scald development is allowed to vary from year to year, but the effect of harvest date is forced to be the same for all years. For Equation C, the assumption is made that the base rate of scald is the same in all years, but that the influence of harvest date may vary from year to year. In Equation D both the constant and the coefficient for harvest date are allowed to vary from year to year.

Comparisons were made to see if imposition of these restraints affected the equations' abilities to describe variation in scald incidence. Chow's test was used to compare pairs of equations to determine if the unrestrained equation was significantly different from the equation in which restraints were imposed in describing variation in scald development. Chow's F is shown in the last column of Table 4.4. The significant F for the comparison of Equations A vs B shows that the base rate of scald development was not the same in all years when the one variable used to describe variation in scald incidence was harvest date. This suggests that something varies from year to year, in addition to harvest date, that influences scald development (no surprise). The significant F for the comparison of Equations A vs C shows that if the base rate of scald is not allowed to vary from year to year, the influence of harvest date on scald development does vary from year to year. The nonsignificant F values for the comparisons of Equations B vs D and C vs D show that allowing both coefficients to vary does not improve the equations' abilities to describe scald variation over allowing only one coefficient to vary.

While Table 4.4 shows how scald was related to harvest date, Tables 4.5, 4.6, 4.7, and 4.8 show how scald also was related to number of preharvest days with temperatures recorded at or below 6°C, 8°C, 10°C, and 12°C, respectively. In the initial equations (A), the temperature cutoff of 8°C gave the best result in terms of R^2 of comparable equations (Table 4.6 vs Tables 4.5, 4.7, and 4.8). The assumption is made that the equation which describes the highest percentage of variation in scald development (i.e. has the highest R^2) will be of the most value later in predicting scald based on preharvest factors. When the years were separated (Equations B, C and D), equations using the 12°C and 10°C temperature cutoffs were slightly more effective in describing scald variation than was the equation using the 8°C cutoff; the 12°C cutoff was slightly better overall than the 10°C cutoff. It is evident that if the years are to be separated at all, these equations cannot be used for predictions, only for descriptions of relationships between scald and its related factors within given years.

While the exact relationships varied from year to year, it still may be possible to combine the data in a meaningful and predictive way. The following equation (Equation 1) combining 210 cases collected over a period of seven years was constructed:

Percent scald= 103 - 0.265 (harvest day after Sept 1(DA)) - 1.92 (preharvest days at or below 8°C(D8)) - 5.94 (harvest starch score(ST)).

It yielded an R^2 of 0.60. All independent variables had negative coefficients. T-ratios with 206 df were -0.63 for DA, -3.34 for D8, and -4.07 for ST. Sixty percent of the variablity in scald could be explained by the variability in these factors, but again when separate equations were made for each year, as in the "B" equations in Tables 4.5-4.8, the R^2 increased to 0.77, and Chow's test showed that separating the equations by year would have been appropriate. While it is clear that scald reduction was a function of these measured variables, either something else which was influencing scald development was varying from year to year, or the data needed to be arranged differently.

While evaluating the 1993 fruit for scald, an unusual phenomenon was observed. Scald normally decreases with later harvest, but the fruit harvested late in this year showed an increase in scald over earlier harvests. Figure 4.1 shows the relationships between scald incidence and harvest date, preharvest days at or below 8°C, and harvest starch score in 1993, demonstrating that this anomaly conflicted with all three usual indicators of declining scald susceptibility. This trend toward increasing scald at late harvests also was observed in other experiments which were being conducted at the HRC during the 1993 season. The 1993 increase in scald susceptibility with later harvest began on October 8, when starch score averaged 6 and there had been 18 days with temperatures at or below 8°C. In three years other than 1993 the harvest also continued as late as October 8 (Table 4.1). Starch scores as high as 6.0 occurred in all years except 1987, and there had been at least eighteen days below 8°C before the end of harvest in 1991 and 1992 as well as in 1993 (Table 4.1). Therefore, something other than these three factors, as used in these equations, or some interaction among these factors, must have been contributing to this increase in scald.

Ripening, accumulated low temperatures, and date of harvest all increase with time, but average daily light exposure and rainfall do not necessarily do so. Rainfall trends after 01 September for each year, 1985 through 1993, are shown in Figure 4.2. The years of lowest rainfall, 1986, 1988, and 1992, are not clearly separated in the figure, but were quite similar to one another.

Figure 4.3 shows that among these nine years, light scores increased late in the season in three of the years, 1985, 1986, and 1987. Light scores, assigned as previously described, are subjective, but it is possible that an effect of light on scald development may be found if such an effect exists. While daylength declines as the picking season progresses, in some years late season reduction in light duration may be counterbalanced by cloudy weather early in the picking season, i.e. short sunny days may supply more light than long cloudy or rainy days. Figure 4.3 suggests this may have been the case in 1985, 1986, and 1987.

Although rainfall and light scores over all years were not directly related to scald susceptibility when all years were combined, with correlation coefficients of -0.08 and -0.06, respectively, in some individual years these factors were significantly correlated to scald development (Tables 4.9 and 4.10). This was sometimes a positive and sometimes a negative relationship. Often the relationship approximately equalled, but was opposite in sign to the relationship between rainfall or light score and days with temperatures at or below 8°C (Tables 4.9 and 4.10, last two columns). Only in 1985 and 1993 were there significant correlations between light score and scald without a significant opposite relationship between light score and number of preharvest days with recorded temperatures at or below 8°C (Table 4.10). In 1985 average light score in the week before harvest was correlated with scald, but not with number of preharvest days with recorded temperatures at or below 8°C, and in 1993 average light score from 02 September (03 September is for leap years) to harvest was correlated with scald, but not with number of preharvest days with recorded temperatures at or below 8°C. In 1985 average rainfall from 02 September to harvest was significantly correlated to scald, but not to number of preharvest days with recorded temperatures at or below 8°C (Table 4.9). Because (a)there is a consistent negative correlation between preharvest days with recorded temperatures at or below 8°C and poststorage scald, and (b)the relationships between rainfall or light score and scald are not consistent, and (c) usually the relationship between rainfall or light score and scald is opposite to the relationship between preharvest days with recorded temperatures at or below 8°C and scald, it is quite possible that the correlations between light or rainfall and scald are merely a reflection of the relationship between preharvest days with recorded temperatures at or below 8°C and scald. When the two factors, average cm rainfall from 02 or 03 September to harvest and average light score from 02 or 03 September to harvest were added to Equation 1, Equation 2 was produced as follows:

%Scald = 141 - 1.6DA - 0.60D8 - 3.7ST + (0.40*average daily mm rain 02 Sept to harvest) - (55*average daily light score 02 Sept to harvest). the resulting R^2 of 0.63 was only slightly higher than the R^2 of Equation 1 (0.60). However, when just the 1993 data were used, with the unusual increase in scald in late-picked fruit, inclusion of rainfall and light variables increased the R^2 of the equation from 0.61 to 0.74 (compare Equation 3 to Equation 4 in Table 4.11). This equation including light and rainfall factors, being completely linear, could not completely describe the late season rise in scald susceptibility in 1993 (Figure 4.4). The result of adding light and rainfall factors to an equation describing poststorage scald incidence was more dramatic when applied to the 1985 data (1993 and 1985 were the two years that included light and/or rainfall data which correlated with scald, but not with D8). Equations 5 and 6 in Table 4.11 show that in 1985 adding factors for rainfall and light increased the R^2 of the equation from 0.69 to 0.94. Because starch was not measured in 1985, starch was excluded from the 1985 equations. When starch was excluded from the multiyear equation relating scald to harvest date (DA) and number of preharvest days with temperatures at or below 8°C (D8) either with or without rainfall (RAIN) and light (SUN) factors, the number of cases increased to 358. The resulting equations, either without rainfall and light factors (Table 4.11, Equation 7), or with rainfall and light factors (Table 4.11, equation 8) produced R^2 values of 0.58 and 0.60, respectively, which were lower than the R^2 values of the equations that had included starch, 0.60 and 0.65, respectively (Table 4.11, Equations 1 and 2). Thus, the equations created using the 210 cases including starch, rather than the entire data set of 358 cases, produced a better description of scald susceptibility.

In all of the combined-years equations (Table 4.11, Equations 1, 2, 7, and 8), harvest date, number of preharvest days at or below 8°C, starch score, average daily cm rain from 02/03 September to harvest, and average daily light score from 02/03 September to harvest, all had either negative or nonsignificant coefficients. The significance of these coefficients must be viewed with some caution, however, since many of the "independent" variables are correlated. This does not mean that the equations are not meaningful, only that the individual contributions of the variables cannot be determined.

In all of the equations in Table 4.11, as well as in those in Tables 4.4 through 4.8, the assumption has been made that the relationships between scald and the various preharvest factors are linear. This assumption is certainly not valid over an indefinite range of at least some of the variables. The rise in scald incidence in late-picked fruit in 1993, described above, demonstrates this. During the first two weeks of September, before commercial harvest of 'Cortland' typically begins in Massachusetts, "number of days from 01 September" is increasing at a rate of one per day, but the number of 'Cortland' fruit which are likely to scald following storage if harvested during this period is a constant 100%. If the relationship between two variables is not linear, but is mistakenly considered to be linear, erroneous conclusions may result. An example of this is given in Figure 4.5 which depicts the function $Y=\ln(101-X)$. It also shows the erroneous prediction line $Y_{pred}=5.11-(0.324)X$ which was generated using the data points shown. The R^2 of this "prediction" equation is 0.75. If an R^2 of 0.75 is obtained in a situation in which one is trying to explain variation in scald on stored apples, that would be considered quite successful. However, in this example, the linear relationship depicted is not appropriate. One way of assessing the appropriateness of a function in describing data is to look at the residuals, the differences between the actual data points and the points as predicted. If there is a pattern to the residuals, then it is likely that the prediction equation is less than ideal. In the case of Figure 4.5, the residuals do show a definite pattern; the error terms of the predictions are correlated to the predictions themselves. The Durbin-Watson "d" statistic (Durbin and Watson 1950, 1951) can be used to test for the presence of this autocorrelation. The Durbin-Watson d (Durbin and Watson, 1951) for the prediction equation in Figure 4.5 is 0.55, which is significant at P=0.01, indicating the presence of autocorrelated error terms.

The last column of Table 4.11 shows the Durbin-Watson d statistic for each of the equations. The further the d value is from 2.00, the stronger is the relationship between prediction error and scald percentage. All of the d values in Table 4.11 are significant at P=0.01. This means that the prediction errors do vary according to scald percentage. In practical terms, this may or may not be important. The trends detected using the Durbin-Watson d statistic may be small enough to ignore, but do need to be considered to determine if this is important from a practical standpoint.

Testing Prediction Equations

In order to test an equation and observe some actual prediction errors, data from the seven years for which the relevant variables were available were combined (210 cases), and a random subsample of 32 was saved for testing the equation developed. Equation 3 was developed using the remaining 178 cases:

% Scald= 135 - (1.6 * harvest day after Sept 1) - (0.42 * number of days at or below 8°C) - (0.82* average daily mm rain from 02 or 03 Sept to harvest) - (49 * avg daily score from 02 or 03 Sept to harvest) - (4.0 * harvest starch score).

The R^2 for this equation was 0.63 and was significant at P=0.01. The subsample then was used to test the equation, and the result is shown in Figure 4.6. There is a great deal of scatter among the data. When actual scald was less than 60%, scald was underpredicted in 4 cases and overpredicted in 9 cases. Conversely, when actual scald was over 60%, scald was underpredicted 14 times and overpredicted only once. Thus, the trend was to overpredict when scald was low and to underpredict when scald was high. This autocorrelation of error had been indicated by the significant Durbin-Watson d in Equation 2, Table 4.11, from which a subsample of data was used to develop this equation. Leaving out starch to increase the size of the overall database to 358 cases (as was done in Equation 8, Table 4.11) resulted in the following (Equation 4) using 300 cases and reserving 58 random cases for testing:

% Scald = 138 - (1.2 * harvest day after Sept 1) - (2.7 * days at or below 8°C) - (0.027 * average daily mm rain from 02 or 03 Sept to harvest) - (45 * avg daily light score from 02 or 03 Sept to harvest). The R^2 for this equation was 0.60, which was significant at P=0.01. When the remaining 58 cases were used to test the equation, the results were similar to those of the previous equation which had included starch. This second equation included more cases (300 vs 178), but starch was not included as a variable. Figure 4.7 shows that again there was scatter among the results, but, as the highly significant Durbin-Watson test in Table 4.11, Equation 8 indicated, there was auto correlation of error. The trend again was to overpredict where there was little scald, and underpredict where there was a great deal of scald. Specifically, Figure 4.7 shows that when actual scald was less than 60%, scald was underpredicted in 4 cases and overpredicted in 12 cases. Conversely, when actual scald was over 60%, scald was underpredicted 25 times and overpredicted 4 times. Evidently, starch score was of some value as a scald predictor since increasing the size of the database at the expense of starch score reduced both the R^2 and the Durbin-Watson d of the equation (Table 4.11, Equation 2 vs 8). The scatter plots in both Figure 4.6 and reduced both the R^2 and the Durbin-Watson d of the equation (Table 4.11, Equation 2 vs 8). The scatter plots in both Figure 4.6 and Figure 4.7 place over 60 % of the samples in the two catagories, "high" scald underpredicted and "low" scald overpredicted.

Transforming Variables

Because of this tendency for the equations to overpredict the high scald cases and underpredict the low scald cases, various transformations of the data were performed (Table 4.12) in an attempt to remedy this problem. A most successful equation is considered one which produces both a high R^2, indicating that variation in the independent variables explains a high percentage of the variation in scald, and a Durbin-Watson d close to 2.00, indicating that the prediction error is not highly correlated to the scald value itself. Transforming percent scald to $e^{(\text{percent scald}/100)}$, written as exp(scld/100), and transforming the independent variables to either ln(independent variable) or square root (sqrt)(independent variable) gave the most improvement over use of the untransformed data. R^2 was increased from 0.63 to 0.73 if log transformations were used or to 0.70 if square root transformations were used. The Durbin-Watson d's increased from 1.09 to 1.21 or 1.19, respectively. Transforming only the independent variables resulted in intermediate improvements in R^2s. Transforming scald, but not the independent variables, did not improve descriptions of scald variation. The exponential scald transformations, including those with log- and square root-transformed independent variables, were repeated using the 6, 10, and 12°C temperature cutoff data. Results are shown in Tables 4.13, 4.14, and 4.15, and summarized in Table 4.16. Overall, the 6°C (D6) variable was the most successful of the four temperature cutoff variables in increasing R^2, while also increasing the Durbin-Watson d. However, there was very little improvement over using no temperature variable at all, especially in the bottom two rows, which are those with the highest R^2s and d's.

Adding High Temperature Reversal of Low Temperature Effects

None of the above work takes into account the possibility that preharvest high temperatures in autumn might negate the effects of cool temperatures. At least two possible mechanisms for this observed phenomenon exist. First, the effect of hot weather may be to completely negate the cool-temperature-induced reduction in scald susceptibility which had already occurred. For example, a physiological mechanism may need to be turned on, and then produce something which helps the fruit resist scald development. If the high temperature shuts the mechanism off, the counting of cool temperature days or hours might have to restart at zero after a critical high temperature had been reached. Second, the effect of high temperatures merely may be to set back the scald resistance of the fruit to where it had been some number of days or hours of cool temperatures previous to the hot weather occurrence. For example, a substance which confers resistance to scald may only be produced at cool temperatures, and is slowly broken down at warm temperatures. The counting of days or hours below a given temperature might not have to be restarted at zero, but rather would only need to have a warm temperature factor subtracted. Both of these possibilities were examined using the HRC 'Cortland' data.

For the first case, in which high temperatures are assumed to negate totally the low temperature-induced suppression of scald, the variable "number of preharvest days with temperature at or below 6, 8, 10, or 12°C" was replaced with a variable in which days when the particular low temperature was reached were accumulated as before except that whenever the temperature reached 30°C the low temperature day count returned to zero. This variable then replaced the original in the equation. Table 4.17 shows results of this procedure with various transformations of the data. The most successful transformations were those using $e^{(\text{percent scald}/100)}$. The R^2s and Durbin-Watson d's generally were a little higher than when the high temperature effects were not accounted for in this way (compare to Table 4.16). The highest R^2 was 0.74 and came from the equation using $e^{(\text{percent scald}/100)}$ as the dependent variable, with 8°C as the low temperature cutoff and including starch as a variable, and transforming the independent variables to their natural logs.

Tables 4.16 and 4.17 also show some effects of using different sets of data. In nearly every case, the R^2 and d were higher in the equations which used only the 210 cases for which starch was available, again indicating that starch scores were meaningful contributors to the equations, even though the size of the database had to be reduced to include them. Note, however, in Table 4.16, that without using starch or low temperature as variables in equations, the smaller data set resulted in higher R^2s and d's.

For the second scenario, in which high temperatures are assumed to create a setback to the process(es) which reduce(s) scald susceptibility, variables were designed to subtract either one or two days from the accumulated days in which temperatures dropped below 6, 8, 10, or 12°C for each day the temperature exceeded 30°C. Tables 4.18 and 4.19 summarize the equations which describe the relationships between scald development and the independent variables indicated. The transformations of scald to $e^{(\text{percent scald}/100)}$, as before, gave the highest R^2 and d values. Transforming the independent values to either their square roots or their natural logarithms resulted in equations with similar R^2 and d values. Subtracting one or two days of cool temperature for each day at or above 30°C had varying effects depending on the temperature cutoff used. If two days were subtracted for each day at or above 30°C (Table 4.19), the low temperature variable was often zero, and the resulting equations had lower R^2s than corresponding equations in Tables 4.16-4.18. This difference was negligible or nonexistent where 10 or 12°C was used as the temperature cutoff. Including starch score always increased both the R^2 and the

Durbin-Watson d substantially. However, when only the 210 cases for which starch was available were used for the equations excluding starch, the difference was not nearly so great (Table 4.16 shows an example of this). The temperature cutoff of 6°C was overall somewhat better than the other temperature cutoffs, although the highest R^2, 0.74, was for the equation which used $e^{(scald/100)}$ as the dependent variable, ln(var)for the independent variables, and D8D, as described in Table 4.17, as the low temperature variable. The equations using the ln or square root transformations of the 8°C temperature variables, combined with $e^{(scald/100)}$ as the dependent variable were the best overall, considering R^2 and d. For these equations, there was little difference between effectiveness of equations in which days were subtracted for each day of 30°C temperature, those in which the day count restarted after each day of 30°C temperature, and those in which the original number of days with temperature at or below 8°C was used. Further, there was only slight improvement over using no temperature variable at all (compare Tables 4.17, 4.18 and 4.19 to Table 4.16). Thus, the theory that hot weather may create a setback to development of scald resistance or loss of scald sensitivity could not be confirmed or refuted using the quantification methods described above.

Identifying Scald Susceptibility at Harvest

Under field growing conditions there is a great deal of variability in scald susceptibility among individual fruits grown in the same orchard block and harvested at the same time. Thus, it is unrealistic to expect to pinpoint the exact amount of scald that will occur on a given lot of fruit. However, it may not be necessary to do this. If lots of fruit that are unlikely to develop much scald and ones that are very likely to scald could be identified at the time of harvest, this could be quite useful to those making scald-control decisions. To test this possibility, using data from the preceding analyses, samples were categorized as "very susceptible to scald (bad)" if greater than 60% of the fruit in the sample scalded, and "very resistant to scald (good)" if fewer than 20% of the fruit scalded. By creating these categories, it became possible to make two separate equations, one equation to separate the extremely scald-susceptible fruit from the others, and the second equation to separate the especially scald-resistant fruit from the others. These equations then could be used to predict which fruit would be unusually scald-susceptible or unusually scald-resistant.

The procedure used to create these prediction equations was Logit regression (Maddala (1983) and Kennedy (1985)). In this procedure, the dependent variable, in this case percent scald on a lot of fruit, is assigned a value of either zero or one. Equations are then created as previously described, and predictions can be made based on these equations. Using as an example the above case considering "bad" fruit, those lots of fruit in which over 60% of the fruit scalded were assigned a value of one, and all other lots were assigned a value of zero. (In the other case, for which separate equations were developed and tested, lots of fruit in which fewer than 20% of fruit scalded were assigned a value of one, and the others were assigned a value of zero.) The X's were harvest date, as Julian day minus 243 (DA), number of preharvest days with temperatures at or below 6°C or 8°C (D6 and D8, respectively), total mm rainfall from 02 or 03 September to harvest (RAIN), average daily light score from 02 or 03 September to harvest (SUN), and harvest starch score (ST). To test these equations, if the Y value (Index) for an individual case is greater than or equal to 0, Y is considered to be 1. If the Y value is less than 0, Y is considered to be 0. Thus, in the first example in which "bad" fruit were to be separated, a Y value of 1 would predict that over 60% of fruit in a lot would scald after storage, while a Y value of 0 would predict that no more than 60% of fruit in that lot would scald. In the second example, a Y value of 1 would predict that fewer than 20% of fruit in a lot would scald, and a value of 0 would predict that at least 20% of fruit would exhibit poststorage scald.

The data used for this test were both the subsample of the 210 cases for which starch scores were available, and also the entire data set of 358 samples eliminating starch score as a variable. In both sets, about 15% of the data were randomly excluded from use in constructing equations so that they could be used to test results. The independent variables were either untransformed or transformed to their square roots (sqrt), this having been shown previously to be the most successful transformation of the independent variables for the purpose of describing variation in scald susceptibility among fruit samples if starch scores were not available.

The equations constructed without starch scores correctly identified 84 or 83% of the test samples correctly as being "good" or "bad", if the 6°C temperature cutoff was used, and 91 or 90% of the test samples correctly as being "good" or "bad" if the or 8°C was used as the cutoff for cool temperature accumulation (Tables 4.20 and 4.21). When starch was included in the equations, thus reducing the size of the data base but potentially adding useful information, 81 to 88% of the samples were correctly identified as "good" or "bad" (Tables 4.22 and 4.23).

On the surface, these percentages are impressive. However, the equations actually may not predict as well as those percentages imply. If you randomly assigned zeros and ones to sample lots, you would expect to be correct about half of the time if the samples were evenly divided between zeros and ones, as <u>is</u> the case with the "bad" vs "not bad" samples. Hence "% cases correctly placed" is not a very useful value. The last column in the box containing equations in Tables 4.20-4.23 shows Normalized Success Indices (NSI) for the equations. The NSI corresponds to the "R^2" in OLS regression; it indicates the proportion of variation in the Y variable which is described by the X variable(s). This statistic is a number between zero and one, and is calculated as follows: ((no. cases predicted to be correctly predicted zero/ no. cases observed to be zero) - proportion of total observed to be zero) + ((no. cases predicted to be correctly predicted one/ no. cases observed to be one) - proportion of total observed to be one)). A perfect equation would yield a NSI of 1.00, while a random sampling would yield a NSI of zero. The NSI index thus takes into account the ratio of zeros and ones in the sample, and represents a truer picture of an equation's ability to assess differences in scald susceptibility than does a simple "percentage of right predictions".

Looking at Table 4.21, which shows particularly scald-susceptible lots of fruit being separated without harvest starch score in the equations, one can see that Equations B and D, respectively, have higher success rates as measured by NSI than Equations A and C, respectively, showing that the 8°C temperature cutoff resulted in more successful equations than the 6°C cutoff. Note that absolute values of the t-values for D8 (equations B and D) were higher than those for D6 (equations A and C), but absolute values of the t-values for the DA coefficients were correspondingly reduced. Also equations C and D, using the square root transformations, were more successful than those using untransformed data (A and B) whether the 6°C (Equation A vs C) or the 8°C (Equation B vs D) cutoff was used. Table 4.23, using a smaller data set than was used in Table 4.21, with the addition of harvest starch score as a factor, yielded poorer results than those in Table 4.21 if the 8°C factor was used, and better results if the 6°C factor was used. Square root transformations yielded superior results in identifying especially scald susceptible fruit when the 8°C temperature variable was used with starch, and if the 6°C variable was used without starch. In tests of the equations, shown below the equations, the equations with the 6°C variable were more successful in identifying scald susceptible fruit whether square root transformations were used or starch was included in equations. Tables 4.20 and 4.22 show equations for identifying lots of fruit which will be especially scald-resistant. These equations were always less successful, in terms of NSI, than their counterparts in Tables 4.21 and 4.23 which predicted cases of especially scald-susceptible fruit. However, they show the same patterns of superiority of 6 vs 8°C variables and nontransformed vs square root-transformed independent variables.

The boxes below the equations in Tables 4.20-4.23 show results of testing Equations A through D above them. The equations were tested using the randomly reserved data which represented approximately 15% of the total. Because Equation D, which used the 8°C temperature cutoff and the square root transformations, was the most successful overall, that equation will be focused on, but similar patterns can be seen in the tests of the other equations. When testing Logit equations, a sample can fall into one of four categories. A sample which is actually a "zero" can be predicted to be a "zero" or it can be predicted to be a "one". A sample which is actually a "one" can also be categorized as being either a "zero" or a "one". In Tables 4.21 and 4.23, these four possibilities can be interpreted in the following manner. A "one" sample can be thought of as "bad", in that it is very scald susceptible; over 60% of the fruit developed scald. A "zero" sample can be thought of as "not bad" in that no more than 60% of the fruit developed scald. In the example shown in Equation D in Table 4.23, of the 39 samples, 22 were actually "not bad" and 17 were "bad". Of the 22 "not bad" samples, 21 were correctly predicted to be "not bad". In practical terms, this means that only one of the 22 "not bad" samples would have been overtreated for scald had this prediction equation been used. Of the 17 "bad" samples, 15 were predicted "bad", while 2 were predicted to be "not bad", and these 2 samples might have received inadequate anti-scald treatment had the equation's recommendation been followed. Tests of Equation D without inclusion of starch score (Table 4.21) produced results consistent with those in which starch was included (Table

4.23). None of the 23 "not bad" samples were wrongly categorized as "bad", and 6 of the 35 "bad" samples were wrongly categorized as "not bad".

In Tables 4.21 and 4.23, approximately equal numbers of samples were present in the "bad" and "not bad" categories of fruit. In Tables 4.20 and 4.22, however, only 16 percent of the samples were in the "good" category. The NSIs for the "good" "D" equations (Tables 4.20 and 4.22) were 0.453 and 0.350, not nearly as high as those for the "bad" equations (Tables 4.21 and 4.23), 0.575 and 0.500. If Equation D from Table 4.20 had been used as a guide to the scald prevention treatment of the fruit used for testing that equation, only 4 of the 58 lots of fruit would have been predicted to be good. Actually, 7 were good, and only 3 of those 7 lots of fruit in which fewer than 20% developed scald were correctly identified by the equation. In Table 4.22, Equation D was a little more successful. It correctly identified 6 of the 9 especially scald-resistant lots, while placing just one of the "not good" lots in the "good" category. Thus, while use of Logit equations as predictors was somewhat successful, and could have been used to avoid overtreatment of 6 samples, while risking undertreatment of just one, it did fail to identify a substantial percentage (1/3) of scald-resistant lots of fruit.

Substituting Hours for Days of Preharvest Cool Temperatures

In the years 1988, 1990, 1991, 1992, and 1993, hourly temperature measurements were available at the HRC where the 'Cortland' fruit were grown. Using hourly temperature measurements, rather than daily minimum temperatures, in the equations might improve the accuracy of the descriptions of variability in and prediction of scald susceptibility. The number of available samples was reduced from 358 to 225 reflecting the loss of data from 1985, 1986, 1987, and 1989. The number of samples with starch scores was reduced from 210 to 173.

Comparing the simple correlations of number of preharvest days vs hours at or below 6, 8, 10, or 12°C with poststorage scald development, Table 4.1 vs Table 4.24, shows that "number of days" was nearly always more highly correlated with scald than was "number of hours". The exceptions to this were the 8, 10, and 12°C cutoffs in 1990 for which "number of hours" corresponded better to scald, and the 12°C cutoff in 1993 for which "number of days" and "number of hours" were equally correlated to scald. When the simple correlations over all years were compared, the "number of days" had higher correlations with scald when the temperature cutoffs of 6, 8, or 10°C were used, while the "number of hours" had a higher correlation with scald when the 12°C temperature cutoff was used. Tables 4.25 and 4.26 confirm significant intercorrelations among variables. Table 4.27 shows that overall, rainfall variables were not correlated to measured preharvest hours of cool temperatures, and while the correlation coefficient relating the SUN variable to preharvest cool temperature variables was statistically significant, in individual years the correlations were sometimes positive and sometimes negative. These correlations were not at all consistent among years or between light and rainfall. For example, in 1988, both the rainfall and the light variables were correlated negatively with the preharvest cool temperature variables. In 1990, both were positively correlated with the cool temperature variables. The correlations varied some among the four temperature cutoffs, but there was no obvious trend in these differences.

Creating Equations Describing Scald Variation

Because the 10 and 12°C temperature cutoffs seemed from previous analyses the more promising ones when using hourly temperature information, equations using these data were developed. Table 4.28 shows some ordinary least squares (OLS) equations relating poststorage scald development to time of harvest, number of preharvest hours at or below 10 or 12°C, harvest starch score, preharvest rainfall, and preharvest light factors. Equations 1 through 4 include starch as a variable, while Equations 5 through 8 do not. Equations 1, 2, 5, and 6 do not include RAIN or SUN as variables, while Equations 3, 4, 7, and 8 do. In all cases the R^2 was somewhat higher for equations using the 12°C than the 10°C temperature variable. The Durbin-Watson d value was also higher when the 12°C variable was used.

When variables were transformed in the same ways as described previously for the daily temperature variables, the highest R^2 (0.72) was achieved when scald was transformed to $e^{(scald/100)}$, independent variables were transformed to their natural logarithms, and the 12°C temperature cutoff was used (Table 4.29).

Identifying Scald Susceptibility at Harvest

When developing Logit equations to predict especially scald-resistant and especially scald-susceptible lots of fruit, the natural log transformation of independent variables combined with using the 12°C temperature cutoff was expected to be the most successful predictor based on previously described results. Logit equations were developed as they had been when using the daily temperature variables, except that natural logarithm transformations were used where square root transformations had been used before. Tables 4.30-4.33 show the Logit equations developed and the results of tests of the equations. Tables 4.30 and 4.31 show equations for predicting which lots of fruit would be especially scald-susceptible. The Normalized Success Indices (NSI) show that Equations C and D, which used ln transformations of the independent variables, produced equations that were equivalent to Equations A and B using untransformed data. The equations based on 195 lots of fruit, but without a harvest starch variable (Table 4.31), were slightly better in terms of NSI and percent cases correctly placed than were the equations based on 152 lots of fruit and incorporating a harvest starch variable (Table 4.30). The tests of the equations in Tables 4.30 and 4.31 gave somewhat different results than those in Tables 4.21 and 4.23, all of which were designed to identify especially scald-susceptible fruit. In Tables 4.30 and 4.31, "bad" lots were quite effectively identified (8 of 9 for Table 4.30; 12 of 13 for Table 4.31). Of the lots in which 60% or fewer fruit scalded, 4 of 12 were misidentified in Table 4.30, and 4 of 17 were misidentified in Table 4.31. Equations D in Tables 4.21 and 4.23 did not overpredict scald as much. However, they did fail to identify more of the "Bad" lots of fruit. Overall results are promising, with the "daily" equations identifying more of the "Not bad" lots and the "hourly" equations misidentifying fewer of the "Bad" lots.

Tables 4.32 and 4.33 show equations for predicting especially scald resistant lots of fruit. In these cases the Normalized Success Indices (NSI) show that equations C and D, which used ln transformations of the independent variables, had higher NSI's than did Equations A and B which used untransformed data. Equations using the 12°C cutoff were better than those using the 10°C cutoff when ln transformed data were used, but equations using the 10°C variable had higher NSI's when the data were not transformed. Again, the equations based on 195 lots of fruit, but without a harvest starch variable (Table 4.33), had slightly higher NSI values than the equations based on 152 lots of fruit and incorporating a harvest starch variable (Table 4.32). Equation D always had the highest NSI. Only 1 of 18 (Table 4.32) or 1 of 23 (Table 4.33) "not good" lots of fruit were placed in the "good" category. No "Good" lots were misidentified by Equation D, Table 4.32, and only 1 was misidentified by Equation D, Table 4.33. While both the "daily" (Tables 4.20 and 4.22) and the "hourly" (Tables 4.32 and 4.33) D equations correctly placed nearly all of the "Not good" lots, the "hourly" equations were more successful in identifying the "Good" ones. It is not clear what effects the differences in data sets used may have had on these results.

Light and Rainfall Variables

For all the preceding analyses which included light and rainfall factors, the forms of those variables were arbitrarily set as average values from day 246 (02 September or ,if a leap year, 03 September). A number of different forms of these variables are tested to see if some other way of expressing light or rainfall would be better. Since previous results had shown harvest date and number of days with temperatures at or below 8°C to be of value in describing scald variation, these variables were used with the light variables. The three light variables used were 1) average daily light score from day 236 (23 August or, if a leap year, 24 August) to harvest; 2) average daily light score from day 246 (02 September or, if leap year, 03 September) to harvest; and 3) average daily light score of the week immediately preceding harvest. Table 4.34 shows results of testing these three forms of light measurement in equations describing scald variation in the 'Cortland' fruit. The equations in Table 4.34 are set up in four groups of four equations. Each group contains equations in which the data have been similarly transformed. Within each group, the first equation represents the basic equation without any light factor included. Each of the other three equations contains the basic variables plus a light variable. In each of the four groups, regardless of which data set was used, the light variable for average light during the week before harvest gave an equation with the smallest improvement in R^2 and Durbin-Watson d value. The other two light variables always increased both the R^2 and the Durbin-Watson d values. There was no clear difference between beginning the count at day 236 or at day 246.

Table 4.35 shows rainfall data subjected to analyses similar to those to which the light data were subjected. For the short term preharvest variable, though, average rainfall for 3 weeks, rather than one week directly preceding harvest, was used. The addition of rainfall variables to the equations did not give the improvements that the addition of light variables did. The short-term rainfall variable contributed the least. When the full set of 358 cases was used to make equations, none of the rainfall variables generated an increase in R^2 of more than 0.02. Using only 210 cases, representing 7 rather than 9 years, additions of rainfall variables to equations improved R^2s from 0.00 to 0.05. The highest R^2s were obtained when the scald variable was transformed to $e^{(scald/100)}$ and independent variables were transformed to natural logarithms.

In no case did the addition of the rainfall variable improve the equation by more than 0.01 in the R^2 category or 0.03 in the Durbin-Watson d-value category (Table 4.36). Despite the small increases in R^2, when either light or rainfall variables were added to equations, the t-value of its coefficient was statistically significant at P=0.05.

Summary

Equations developed relating preharvest cool temperatures, date of harvest, preharvest rainfall and light factors, and harvest starch score to poststorage development of superficial scald could explain up to 74% of the variation in scald incidence. Logit equations developed to predict instances of high degrees of susceptibility to scald (over 60% of fruit in a lot developing scald) identified with reasonable success scald susceptible lots of fruit. Logit equations developed to predict instances of low susceptibility to scald (fewer than 20% of fruit in a lot developing scald) were less consistent in identifying such lots of fruit, but when hourly temperature data were used they showed promise.

From this intense analysis of the 'Cortland' data, the more promising procedures were chosen for analyzing the much larger data base for 'Delicious' apples from widely varying growing conditions.

Table 4.1 Correlations of poststorage scald incidence on Massachusetts-grown 'Cortland' apples with harvest date, harvest fruit maturity, and preharvest cool temperatures.

Variable	Year	n	Minimum	Maximum	Mean	Corr w/ scald
Harvest date (days after full bloom)	all	358	113	167	140	-0.58[z]
Harvest date	all	358	01 Sept	28 Oct	27 Sept	-0.72
	1985	59	12 Sept	07 Oct	23 Sept	-0.82
	1986	19	17 Sept	05 Oct	24 Sept	-0.66
	1987	15	14 Sept	28 Sept	21 Sept	-0.91
	1988	48	15 Sept	06 Oct	26 Sept	-0.90
	1989	40	06 Sept	04 Oct	23 Sept	-0.88
	1990	51	01 Sept	11 Oct	27 Sept	-0.83
	1991	60	03 Sept	15 Oct	29 Sept	-0.89
	1992	31	15 Sept	28 Oct	29 Sept	-0.82
	1993	35	14 Sept	12 Oct	30 Sept	-0.75
Maturity (starch score)	all	210[y]	1.0	7.1	3.7	-0.72
	1987	15	1.2	4.4	2.6	-0.76
	1988	24	1.1	6.5	3.0	-0.83
	1989	22	1.0	5.6	2.4	-0.93
	1990	27	1.0	7.1	3.3	-0.74
	1991	60	1.0	7.1	4.9	-0.89
	1992	27	1.3	7.0	3.9	-0.81
	1993	35	1.1	6.1	3.6	-0.69
Preharvest days at or below 6°C	all	358	0	25	5.8	-0.66
	1985	59	1	6	4.5	-0.46
	1986	19	8	10	9.6	-0.25ns[x]
	1987	15	1	4	2.0	-0.93
	1988	48	3	10	6.5	-0.90
	1989	40	0	9	2.9	-0.98
	1990	51	0	10	6.0	-0.88
	1991	60	0	14	5.9	-0.87
	1992	31	1	25	6.4	-0.76
	1993	35	2	17	9.1	-0.68

Table 4.1 cont.

Variable	Year	n	Minimum	Maximum	Mean	Corr w/ scald
Preharvest days at or below 8°C	all	358	0	36	9.2	-0.75
	1985	59	1	10	6.3	-0.70
	1986	19	10	13	11.9	-0.55*[w]
	1987	15	5	10	7.0	-0.96
	1988	48	7	15	10.8	-0.88
	1989	40	5	16	9.2	-0.98
	1990	51	0	13	7.5	-0.88
	1991	60	1	19	9.5	-0.89
	1992	31	6	36	13.3	-0.78
	1993	35	2	18	9.9	-0.71
Preharvest days at or below 10°C	all	358	0	50	14.8	-0.72
	1985	59	1	14	8.3	-0.74
	1986	19	17	26	21.1	-0.67
	1987	15	14	21	17.3	-0.95
	1988	48	12	22	16.8	-0.88
	1989	40	9	21	14.1	-0.98
	1990	51	0	19	10.8	-0.84
	1991	60	3	25	14.0	-0.90
	1992	31	14	60	24.8	-0.83
	1993	35	6	28	17.7	-0.74
Preharvest days at or below 12°C	all	358	2	63	21.7	-0.63
	1985	59	6	21	13.5	-0.81
	1986	19	20	31	24.5	-0.72
	1987	15	23	34	28.3	-0.95
	1988	48	15	28	21.0	-0.87
	1989	40	19	33	26.1	-0.97
	1990	51	2	28	17.6	-0.85
	1991	60	7	33	20.4	-0.90
	1992	31	23	63	34.9	-0.82
	1993	35	10	35	23.4	-0.74

[z] All correlations in this column are significant at $P \leq 0.01$ unless otherwise noted.
[y] Fewer cases include maturity than harvest date and temperature data.
[x] ns = not significant at $P = 0.05$.
[w] * = significant at $P \leq 0.05$, but not at $P \leq 0.01$.

Table 4.2 Correlations among variables relating to 'Cortland' fruit grown at HRC from 1987 to 1993. N=210.

Day[z]	+0.86[y]						
DAFB[x]	+0.90	+0.87					
Days[w] ≤ 6°C	+0.76	+0.91	+0.78				
Days[w] ≤ 8°C	+0.75	+0.92	+0.69	+0.92			
Days[w] ≤ 10°C	+0.66	+0.85	+0.57	+0.83	+0.95		
Days[w] ≤ 12°C	+0.59	+0.79	+0.49	+0.72	+0.90	+0.97	
SCALD	-0.72	-0.75	-0.64	-0.64	-0.73	-0.66	-0.59
	Starch[v]	Day	DAFB	Days ≤ 6°C	Days ≤ 8°C	Days ≤ 10°C	Days ≤ 12°C

[z] Day = harvest date as days after 01 September.
[y] All correlation coefficients are significant at P ≤ 0.01.
[x] DAFB = harvest date as days after full bloom.
[w] Days = number of days with recorded temperature.
[v] Starch = starch score at harvest.

Table 4.3 Correlations among variables relating to 'Cortland' fruit grown at HRC from 1985 to 1993. N=358. Note that this table includes 148 cases excluded from Table 2, above, for which no starch scores were available.

DAFB[z]	+0.87[y]					
Days[x] ≤ 6°C	+0.86	+0.75				
Days[x] ≤ 8°C	+0.88	+0.67	+0.91			
Days[x] ≤ 10°C	+0.80	+0.54	+0.80	+0.93		
Days[x] ≤ 12°C	+0.76	+0.48	+0.69	+0.89	+0.96	
SCALD	-0.72	-0.58	-0.66	-0.75	-0.72	-0.63
	Day[w]	DAFB	Days ≤ 6°C	Days ≤ 8°C	Days ≤ 10°C	Days ≤ 12°C

[z] DAFB = harvest date as days after full bloom.
[y] All correlation coefficients are significant at P ≤ 0.01.
[x] Days = number of days with recorded temperature.
[w] Day = harvest date as days after 01 September.

Table 4.4 Estimates of scald incidence on HRC-grown 'Cortland' apples based on harvest date.

Equation		R^2	Error SS	Chow's F
A	Percent Scald= $B_0 + B_1 DAY$[z]	0.52	177930	
B	Percent Scald= B_0, constant if 1985 + B_9DAY B_1, constant if 1986 + B_9DAY B_2, constant if 1987 + B_9DAY B_3, constant if 1988 + B_9DAY B_4, constant if 1989 + B_9DAY B_5, constant if 1990 + B_9DAY B_6, constant if 1991 + B_9DAY B_7, constant if 1992 + B_9DAY B_8, constant if 1993 + B_9DAY	0.78	80492	A vs B F=4.65 **[y]
C	Percent Scald= $B_0 + B_1$ (coef if 1985)DAY $B_0 + B_2$ (coef if 1986)DAY $B_0 + B_3$ (coef if 1987)DAY $B_0 + B_4$ (coef if 1988)DAY $B_0 + B_5$ (coef if 1989)DAY $B_0 + B_6$ (coef if 1990)DAY $B_0 + B_7$ (coef if 1991)DAY $B_0 + B_8$ (coef if 1992)DAY $B_0 + B_9$ (coef if 1993)DAY	0.78	82071	A vs C F=4.49 **
D	Percent Scald= B_0, if 1985 + B_9 (if 1985)DAY B_1, if 1986 + B_{10} (if 1986)DAY B_2, if 1987 + B_{11} (if 1987)DAY B_3, if 1988 + B_{12} (if 1988)DAY B_4, if 1989 + B_{13} (if 1989)DAY B_5, if 1990 + B_{14} (if 1990)DAY B_6, if 1991 + B_{15} (if 1991)DAY B_7, if 1992 + B_{16} (if 1992)DAY B_8, if 1993 + B_{17} (if 1993)DAY	0.82	67355	A vs D F=2.47 ** B vs D F=0.29 ns C vs D F=0.33 ns

[z] DAY = Harvest date, given as days after 01 September.
[y] ns=not significant at P=0.05; *=significant at $P \leq 0.05$; **= significant at $P \leq 0.01$.

Table 4.5 Estimates of scald incidence on HRC-grown 'Cortland' apples based on number of days with temperatures recorded at or below 6°C.

	Equation	R^2	Error SS	Chow's F
A	Percent Scald= B_0 + B_1COOL6[z]	0.43	212630	
B	Percent Scald= B_0, constant if 1985 + B_9COOL6 B_1, constant if 1986 + B_9COOL6 B_2, constant if 1987 + B_9COOL6 B_3, constant if 1988 + B_9COOL6 B_4, constant if 1989 + B_9COOL6 B_5, constant if 1990 + B_9COOL6 B_6, constant if 1991 + B_9COOL6 B_7, constant if 1992 + B_9COOL6 B_8, constant if 1993 + B_9COOL6	0.70	112610	A vs B F=3.42 **[y]
C	Percent Scald= B_0 + B_1 (coef if 1985)COOL6 B_0 + B_2 (coef if 1986)COOL6 B_0 + B_3 (coef if 1987)COOL6 B_0 + B_4 (coef if 1988)COOL6 B_0 + B_5 (coef if 1989)COOL6 B_0 + B_6 (coef if 1990)COOL6 B_0 + B_7 (coef if 1991)COOL6 B_0 + B_8 (coef if 1992)COOL6 B_0 + B_9 (coef if 1993)COOL6	0.72	104120	A vs C F=4.01 **
D	Percent Scald= B_0, if 1985 + B_9 (if 1985)COOL6 B_1, if 1986 + B_{10} (if 1986)COOL6 B_2, if 1987 + B_{11} (if 1987)COOL6 B_3, if 1988 + B_{12} (if 1988)COOL6 B_4, if 1989 + B_{13} (if 1989)COOL6 B_5, if 1990 + B_{14} (if 1990)COOL6 B_6, if 1991 + B_{15} (if 1991)COOL6 B_7, if 1992 + B_{16} (if 1992)COOL6 B_8, if 1993 + B_{17} (if 1993)COOL6	0.79	79585	A vs D F=2.52 ** B vs D F=0.62 ns C vs D F=0.46 ns

[z] COOL6 = Number of preharvest days in which the temperature was 6°C or less.
[y] ns=not significant at P=0.05; *=significant at P≤0.05; **= significant at P≤0.01.

Table 4.6 Estimates of scald incidence on HRC-grown 'Cortland' apples based on number of days with temperatures recorded at or below 8°C.

Equation		R^2	Error SS	Chow's F
A	Percent Scald= B_0 + B_1COOL8[z]	0.56	163640	
B	Percent Scald= B_0, constant if 1985 + B_9COOL8 B_1, constant if 1986 + B_9COOL8 B_2, constant if 1987 + B_9COOL8 B_3, constant if 1988 + B_9COOL8 B_4, constant if 1989 + B_9COOL8 B_5, constant if 1990 + B_9COOL8 B_6, constant if 1991 + B_9COOL8 B_7, constant if 1992 + B_9COOL8 B_8, constant if 1993 + B_9COOL8	0.73	100620	A vs B F=2.41 **[y]
C	Percent Scald= B_0 + B_1 (coef if 1985)COOL8 B_0 + B_2 (coef if 1986)COOL8 B_0 + B_3 (coef if 1987)COOL8 B_0 + B_4 (coef if 1988)COOL8 B_0 + B_5 (coef if 1989)COOL8 B_0 + B_6 (coef if 1990)COOL8 B_0 + B_7 (coef if 1991)COOL8 B_0 + B_8 (coef if 1992)COOL8 B_0 + B_9 (coef if 1993)COOL8	0.74	96270	A vs C F=2.69 **
D	Percent Scald= B_0, if 1985 + B_9 (if 1985)COOL8 B_1, if 1986 + B_{10} (if 1986)COOL8 B_2, if 1987 + B_{11} (if 1987)COOL8 B_3, if 1988 + B_{12} (if 1988)COOL8 B_4, if 1989 + B_{13} (if 1989)COOL8 B_5, if 1990 + B_{14} (if 1990)COOL8 B_6, if 1991 + B_{15} (if 1991)COOL8 B_7, if 1992 + B_{16} (if 1992)COOL8 B_8, if 1993 + B_{17} (if 1993)COOL8	0.82	66829	A vs D F=2.18 ** B vs D F=0.76 ns C vs D F=0.66 ns

[z] COOL8 = Number of preharvest days in which the temperature was 8°C or less.
[y] ns=not significant at P=0.05; *=significant at P≤0.05; **=significant at P≤0.01.

Table 4.7 Estimates of scald incidence on HRC-grown 'Cortland' apples based on number of days with temperatures recorded at or below 10°C.

Equation		R^2	Error SS	Chow's F
A	Percent Scald= B_0 + B_1COOL10[z]	0.51	181220	
B	Percent Scald= B_0, constant if 1985 + B_9COOL10 B_1, constant if 1986 + B_9COOL10 B_2, constant if 1987 + B_9COOL10 B_3, constant if 1988 + B_9COOL10 B_4, constant if 1989 + B_9COOL10 B_5, constant if 1990 + B_9COOL10 B_6, constant if 1991 + B_9COOL10 B_7, constant if 1992 + B_9COOL10 B_8, constant if 1993 + B_9COOL10	0.74	97526	A vs B F=3.29 **[y]
C	Percent Scald= B_0 + B_1 (coef if 1985)COOL10 B_0 + B_2 (coef if 1986)COOL10 B_0 + B_3 (coef if 1987)COOL10 B_0 + B_4 (coef if 1988)COOL10 B_0 + B_5 (coef if 1989)COOL10 B_0 + B_6 (coef if 1990)COOL10 B_0 + B_7 (coef if 1991)COOL10 B_0 + B_8 (coef if 1992)COOL10 B_0 + B_9 (coef if 1993)COOL10	0.76	91128	A vs C F=3.80 **
D	Percent Scald= B_0, if 1985 + B_9 (if 1985)COOL10 B_1, if 1986 + B_{10} (if 1986)COOL10 B_2, if 1987 + B_{11} (if 1987)COOL10 B_3, if 1988 + B_{12} (if 1988)COOL10 B_4, if 1989 + B_{13} (if 1989)COOL10 B_5, if 1990 + B_{14} (if 1990)COOL10 B_6, if 1991 + B_{15} (if 1991)COOL10 B_7, if 1992 + B_{16} (if 1992)COOL10 B_8, if 1993 + B_{17} (if 1993)COOL10	0.83	62333	A vs D F=2.87 ** B vs D F=0.85 ns C vs D F=0.69 ns

[z] COOL10 = Number of preharvest days in which the temperature was 10°C or less.
[y] ns=not significant at $P \leq 0.05$; *=significant at $P \leq 0.05$; **=significant at $P \leq 0.01$.

Table 4.8 Estimates of scald incidence on HRC-grown 'Cortland' apples based on number of days with temperatures recorded at or below 12°C.

	Equation	R^2	Error SS	Chow's F
A	Percent Scald= $B_0 + B_1$COOL12[z]	0.40	223860	
B	Percent Scald= B_0, constant if 1985 + B_9COOL12 B_1, constant if 1986 + B_9COOL12 B_2, constant if 1987 + B_9COOL12 B_3, constant if 1988 + B_9COOL12 B_4, constant if 1989 + B_9COOL12 B_5, constant if 1990 + B_9COOL12 B_6, constant if 1991 + B_9COOL12 B_7, constant if 1992 + B_9COOL12 B_8, constant if 1993 + B_9COOL12	0.75	92840	A vs B F=5.42 **[y]
C	Percent Scald= $B_0 + B_1$ (coef if 1985)COOL12 $B_0 + B_2$ (coef if 1986)COOL12 $B_0 + B_3$ (coef if 1987)COOL12 $B_0 + B_4$ (coef if 1988)COOL12 $B_0 + B_5$ (coef if 1989)COOL12 $B_0 + B_6$ (coef if 1990)COOL12 $B_0 + B_7$ (coef if 1991)COOL12 $B_0 + B_8$ (coef if 1992)COOL12 $B_0 + B_9$ (coef if 1993)COOL12	0.75	93236	A vs C F=5.39 **
D	Percent Scald= B_0, if 1985 + B_9 (if 1985)COOL12 B_1, if 1986 + B_{10} (if 1986)COOL12 B_2, if 1987 + B_{11} (if 1987)COOL12 B_3, if 1988 + B_{12} (if 1988)COOL12 B_4, if 1989 + B_{13} (if 1989)COOL12 B_5, if 1990 + B_{14} (if 1990)COOL12 B_6, if 1991 + B_{15} (if 1991)COOL12 B_7, if 1992 + B_{16} (if 1992)COOL12 B_8, if 1993 + B_{17} (if 1993)COOL12	0.84	60335	A vs D F=4.08 ** B vs D F=0.81 ns C vs D F=0.82 ns

[z] COOL12 = Number of preharvest days in which the temperature was 12°C or less.
[y] ns=not significant at P=0.05; *=significant at P≤0.05; **=significant at P≤0.01.

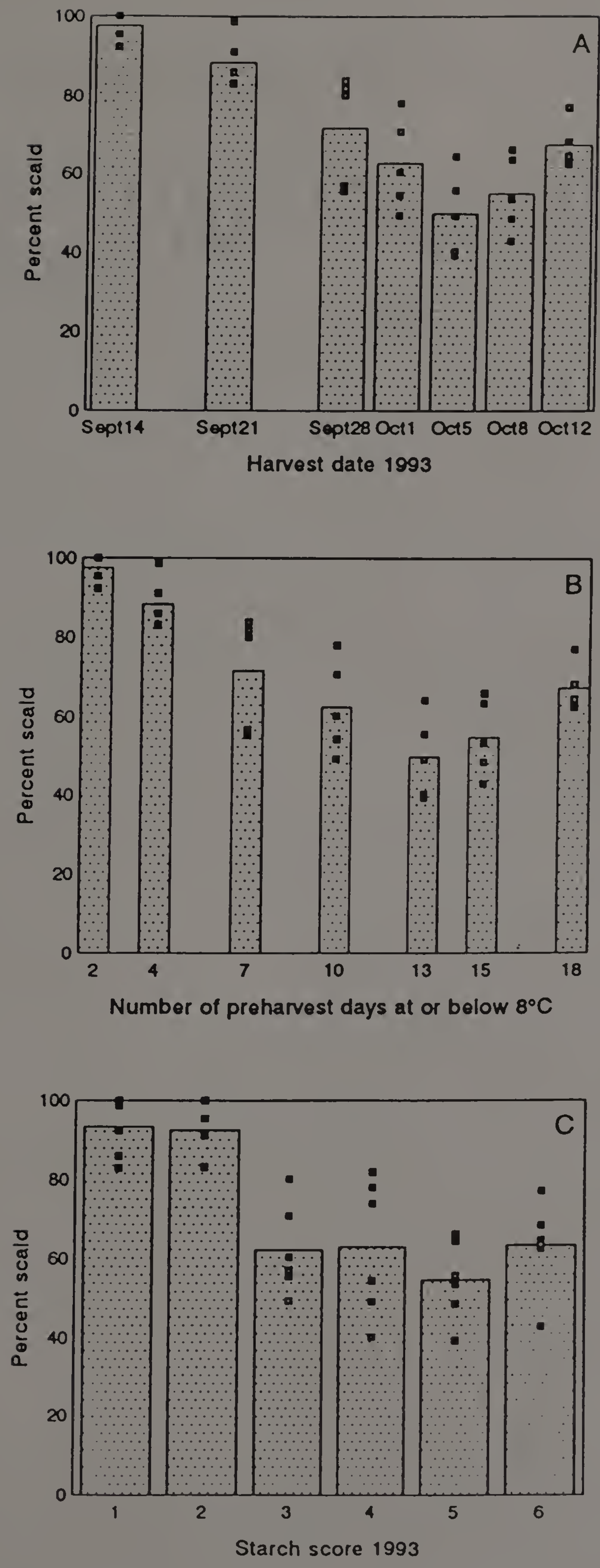

Figure 4.1 Relationships between scald incidence on 'Cortland' apples and harvest date (A), number of preharvest days in which temperature dropped to 8°C or less (B), and starch score (C) in 1993. N=35.

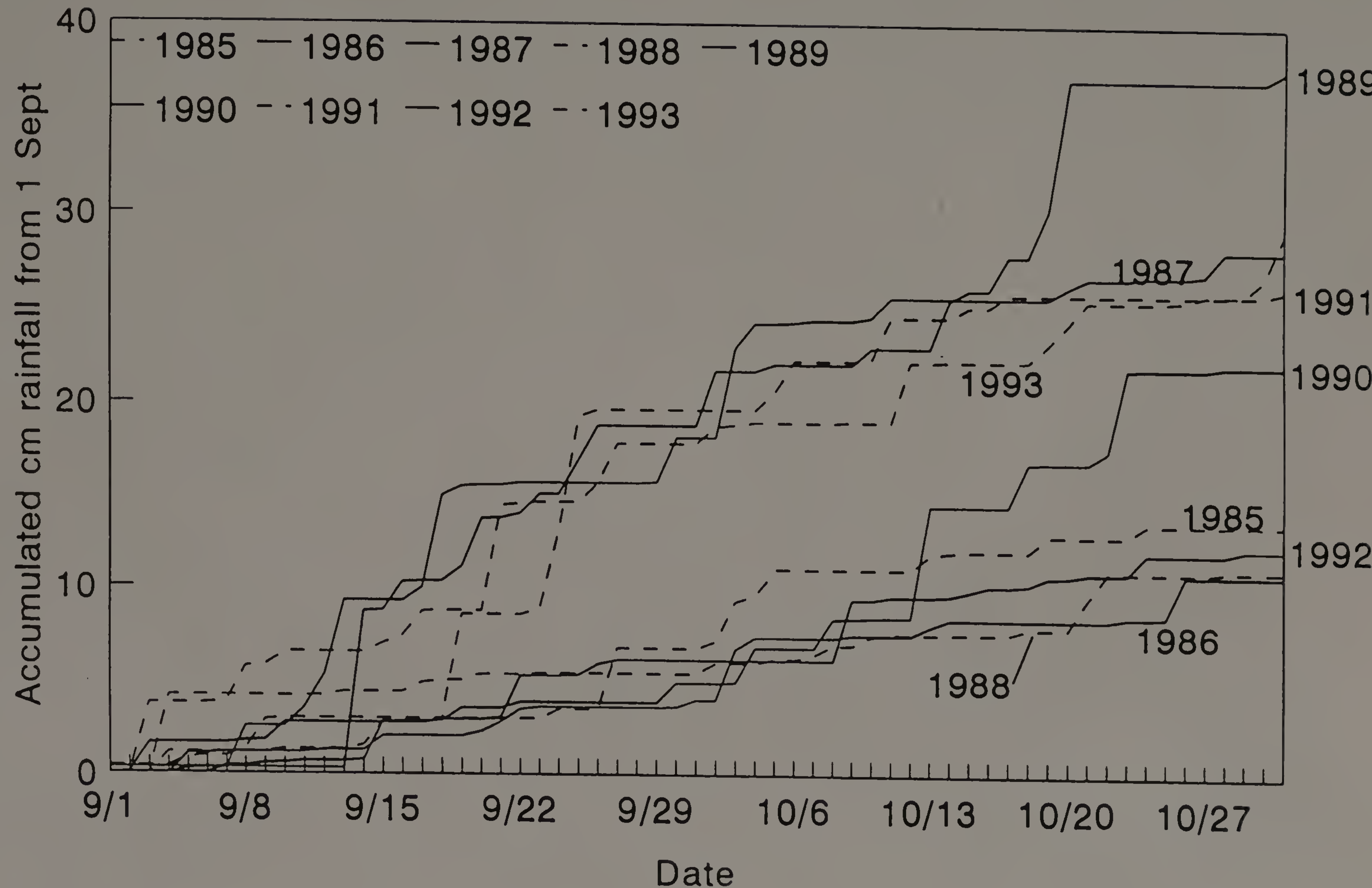

Figure 4.2 Occurrences of rainfall at Quabbin Reservoir, MA from 01 September through 31 October for the years 1985 to 1993. Solid and dotted lines are for aid in reading the graph.

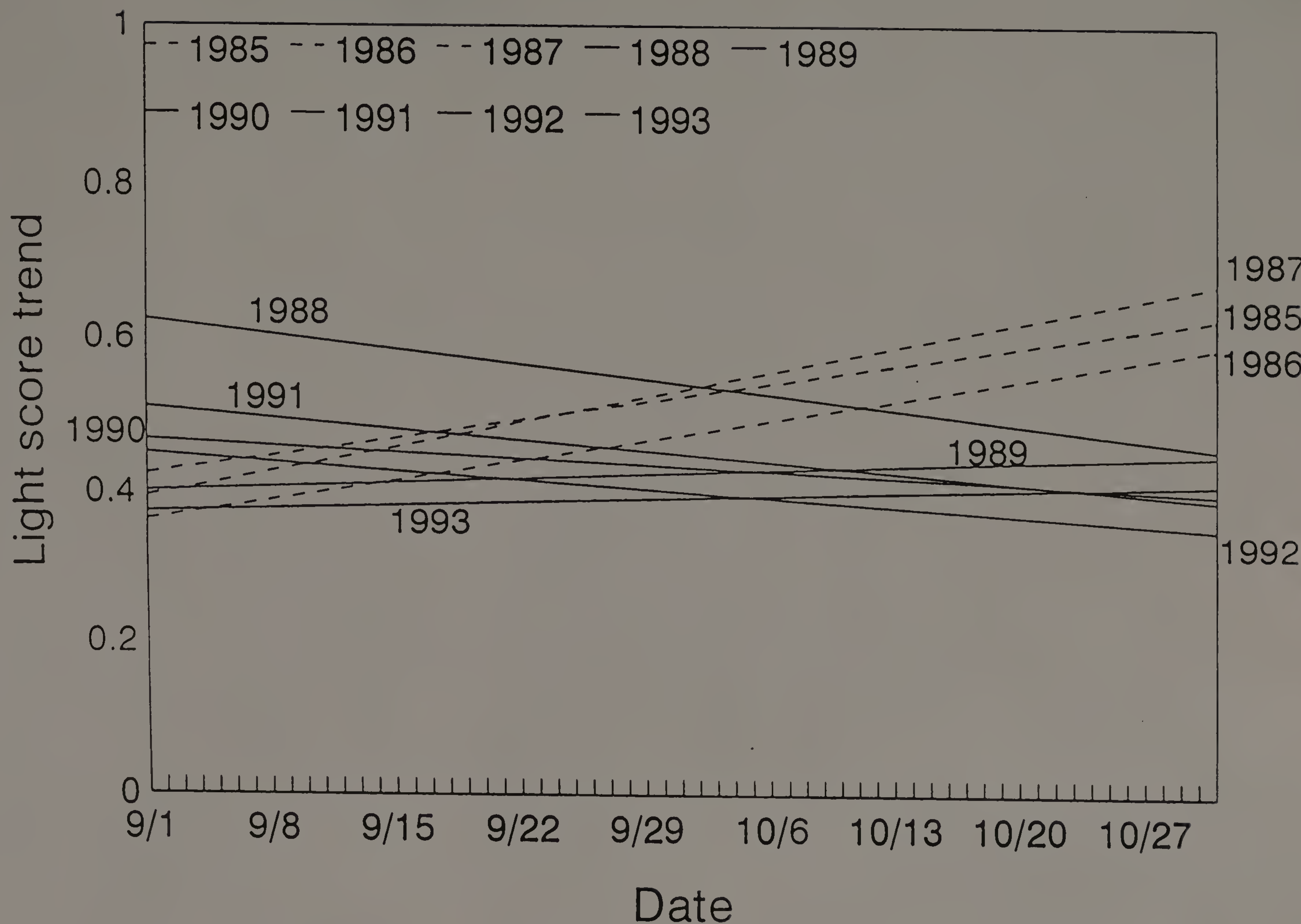

Figure 4.3 Trends in changes in light scores between 01 September and 31 October, 1985 to 1993. Dotted lines indicate years in which the trend was toward increasing light score as time progressed through the period shown.

Table 4.9 Rainfall at the Quabbin Reservoir, correlations between rainfall and scald development on HRC-grown 'Cortland' apples, and correlations between rainfall and number of preharvest days with recorded temperatures at or below 8°C.

Average daily rainfall in mm during indicated period	Year	N	Min	Max	Mean	Corr w/ scald	Corr w/ D8[z]
3 weeks before harvest (HRAIN)	all	358	0.60	10.21	4.21	-0.05[ns] [y]	+0.07[ns]
	1985	59	1.2	6.3	3.6	+0.10[ns]	-0.61**
	1986	19	1.2	2.9	1.5	+0.04[ns]	+0.17[ns]
	1987	15	6.0	7.4	6.9	-0.65**	+0.61**
	1988	48	6.0	4.0	2.0	+0.92**	-0.90**
	1989	40	6.0	10.2	6.8	-0.84**	+0.88**
	1990	51	1.6	5.1	2.1	-0.26[ns]	+0.31*
	1991	60	1.4	9.3	7.5	-0.48**	+0.44**
	1992	31	1.6	2.8	2.0	-0.17[ns]	+0.55**
	1993	35	3.1	6.7	5.2	-0.71**	+0.47**
2/3 Sept to harvest (RAIN246)	all	358	0.00	8.4	3.8	-0.03[ns]	+0.07[ns]
	1985	59	1.2	3.1	2.2	-0.63**	+0.08[ns]
	1986	19	1.4	2.3	1.6	+0.09[ns]	+0.22[ns]
	1987	15	6.2	8.4	7.6	+0.95**	-0.99**
	1988	48	1.8	3.3	2.4	+0.94**	-0.95**
	1989	40	0.0	7.1	6.6	-0.07[ns]	+0.14[ns]
	1990	51	0.0	2.3	1.8	-0.20[ns]	+0.36[ns]
	1991	60	0.0	8.4	5.6	-0.65**	+0.58**
	1992	31	1.7	2.5	2.1	+0.10[ns]	-0.04[ns]
	1993	35	4.8	7.1	5.8	-0.15[ns]	-0.28[ns]

[z] D8= number of preharvest days on which temperatures at or below 8°C were recorded.
[y] [ns]= not significant at P=0.05, *= significant at P≤0.05, **= significant at P≤0.01.

Table 4.10 Light scores at the Quabbin Reservoir, correlations between light scores and scald development on HRC-grown 'Cortland' apples, and correlations between light scores and number of preharvest days with recorded temperatures at or below 8°C.

Average daily light score for indicated period	Year	N	Min	Max	Mean	Corr w/ scald	Corr w/ D8[z]
Week before harvest (SUN1wk)	All	358	0.07	0.86	0.46	-0.06[ns] [y]	+0.11[ns]
	1985	59	0.29	0.86	0.53	+0.53**	-0.06[ns]
	1986	19	0.14	0.50	0.35	+0.55**	-0.94**
	1987	15	0.21	0.64	0.43	-0.93**	+0.94**
	1988	48	0.50	0.64	0.57	+0.08[ns]	-0.35*
	1989	40	0.07	0.71	0.33	-0.41**	+0.39*
	1990	51	0.21	0.71	0.49	-0.47**	+0.50**
	1991	60	0.21	0.79	0.43	+0.18[ns]	-0.16[ns]
	1992	31	0.36	0.57	0.46	-0.02[ns]	-0.32[ns]
	1993	35	0.07	0.86	0.43	-0.22[ns]	+0.72**
2/3 Sept to harvest (SUN246)	All	358	0.28	1.00	0.47	-0.01[ns]	-0.11[ns]
	1985	59	0.28	0.57	0.49	-0.08[ns]	+0.73**
	1986	19	0.36	0.46	0.43	+0.48*	-0.82**
	1987	15	0.36	0.46	0.41	-0.96**	+0.99**
	1988	48	0.59	0.62	0.60	+0.61**	-0.73**
	1989	40	0.37	0.83	0.44	+0.43**	-0.49**
	1990	51	0.32	0.75	0.44	-0.48**	+0.50**
	1991	60	0.39	1.00	0.49	+0.68**	-0.66**
	1992	31	0.38	0.43	0.41	-0.66**	+0.35*
	1993	35	0.34	0.50	0.41	+0.62**	-0.25[ns]

[z] D8= number of preharvest days on which temperatures at or below 8°C were recorded.
[y] [ns]= not significant at P=0.05, *= significant at P≤0.05, **= significant at P≤0.01.

Table 4.11 Some ordinary least squares equations relating poststorage scald on HRC-grown 'Cortland' apples to a variety of variables and data sets.

Equation #	N	Percent scald =	R^2	Durbin-Watson d
1	210	103 - 0.26*DA[z] - 1.9*D8[y] - 5.9*ST[x] t= 22.28**[u] -0.63^{ns} -3.34** -4.07**	0.60	1.01
2	210	141 - 1.6*DA - 0.60*D8 - 3.7*ST + 0.40*RAIN[w] - 55*SUN[v] t= 9.95** -2.92** -1.93^{ns} -2.28* +0.59^{ns} -3.14**	0.63	1.10
3	35	141 - 3.5*DA + 3.5*D8 - 0.45*ST (1993 only) t= 8.30** -2.85** 1.60^{ns} -0.11^{ns}	0.61	0.50
4	35	-86 + 3.1*DA - 6.2*D8 - 1.5*ST + 3.8*RAIN + 265*SUN (1993 only) t= -0.90^{ns} 1.40^{ns} -1.93* -0.32^{ns} 0.69^{ns} 2.68**	0.74	0.78
5	59	145 - 3.4*DA + 3.1*D8 (1985 only) t= 25.05** -6.03** 1.82*	0.69	0.28
6	59	-230 - 0.77*DA - 25*D8 + 56*RAIN + 747*SUN (1985 only) t= -5.40** -2.31* -9.86** 6.90** 9.39**	0.94	1.13
7	358	112 - 0.92*DA - 3.1*D8 t= 31.48** -3.82** -6.84**	0.58	0.90
8	358	139 - 1.3*DA - 2.6*D8 - 0.22RAIN - 46*SUN t= 17.21** -5.03** -5.79** -0.43^{ns} -3.98**	0.60	0.92

[z] DA = Harvest date as days after 01 September.
[y] D8 = Number of preharvest days with temperatures recorded at or below 8°C.
[x] ST = Starch score at harvest.
[w] RAIN = Average daily rainfall in cm from 02 or 03 Sept to harvest.
[v] SUN = Average daily light score from 02 or 03 Sept to harvest.
[u] ^{ns}= not significant at P=0.05, *= significant at $P \leq 0.05$, **= significant at $P \leq 0.01$.

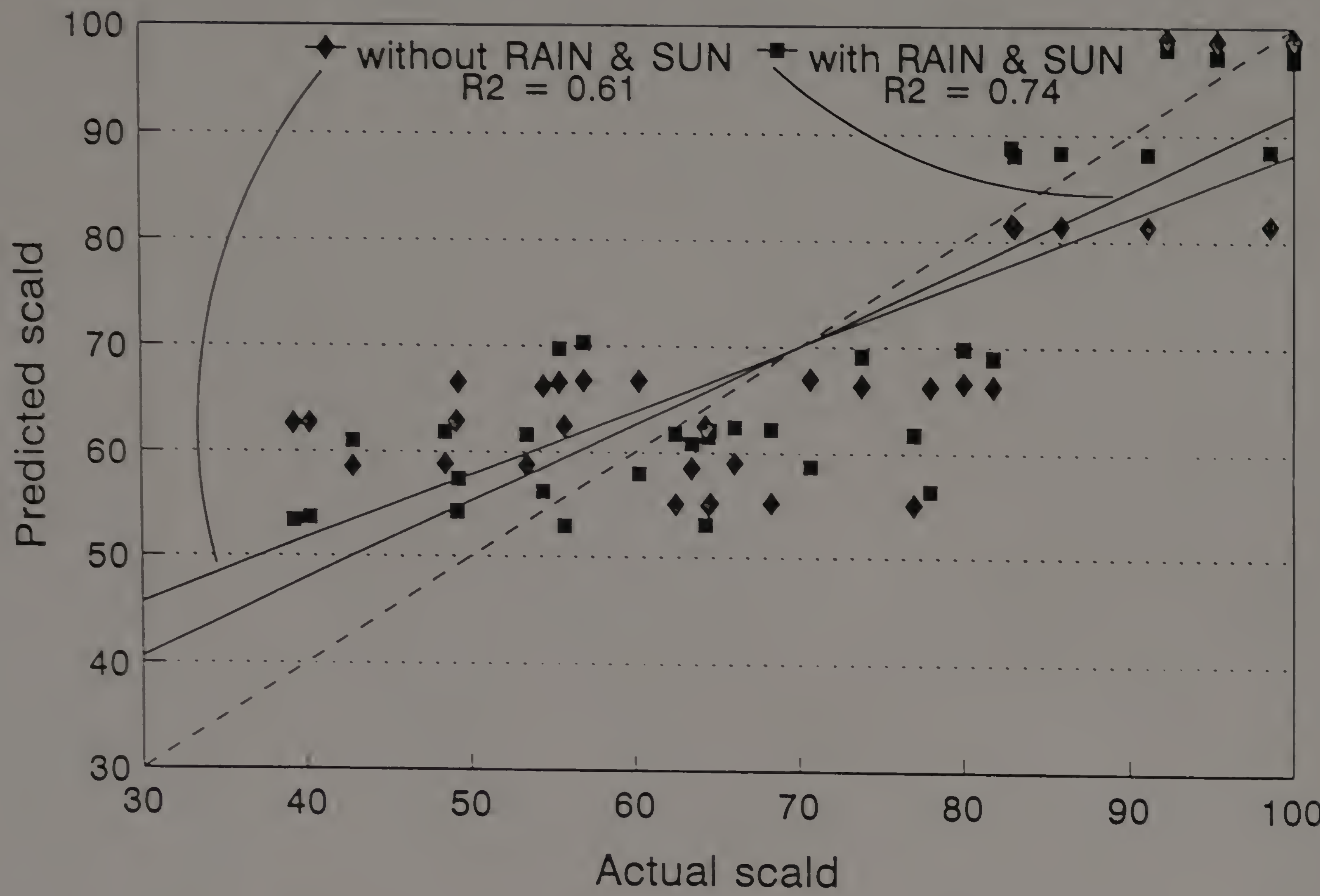

Figure 4.4 Effects of adding light (SUN) and rainfall (RAIN) variables to equations including harvest date, starch, and cool temperature variables describing scald incidence on HRC-grown 'Cortland' apples in 1993.

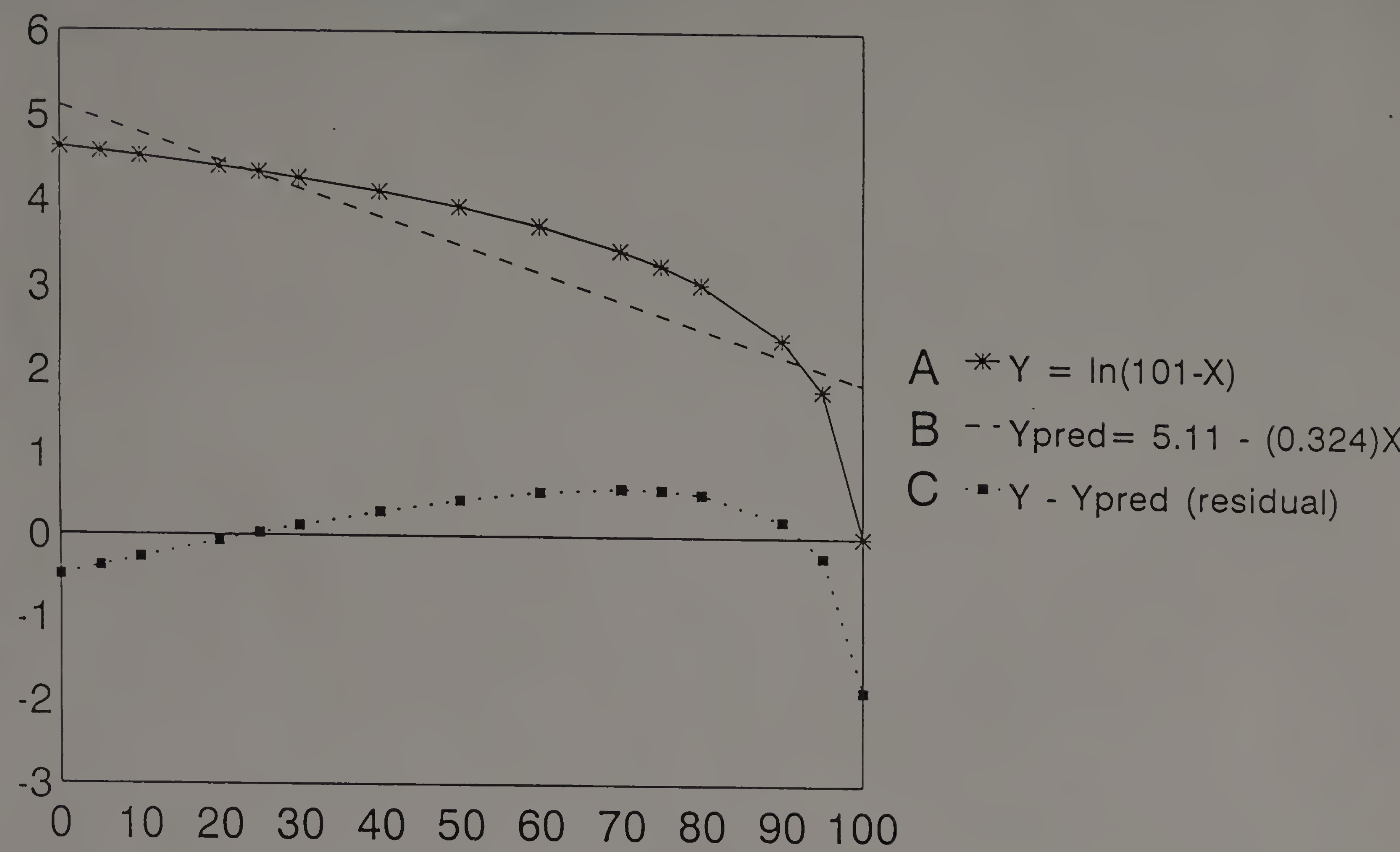

Figure 4.5 A graphic presentation of the error in describing a logarithmic function as a linear function. A) The actual function; B) the linear function derived from the points shown in A); C) the graph of the error (the difference between A) and B)).

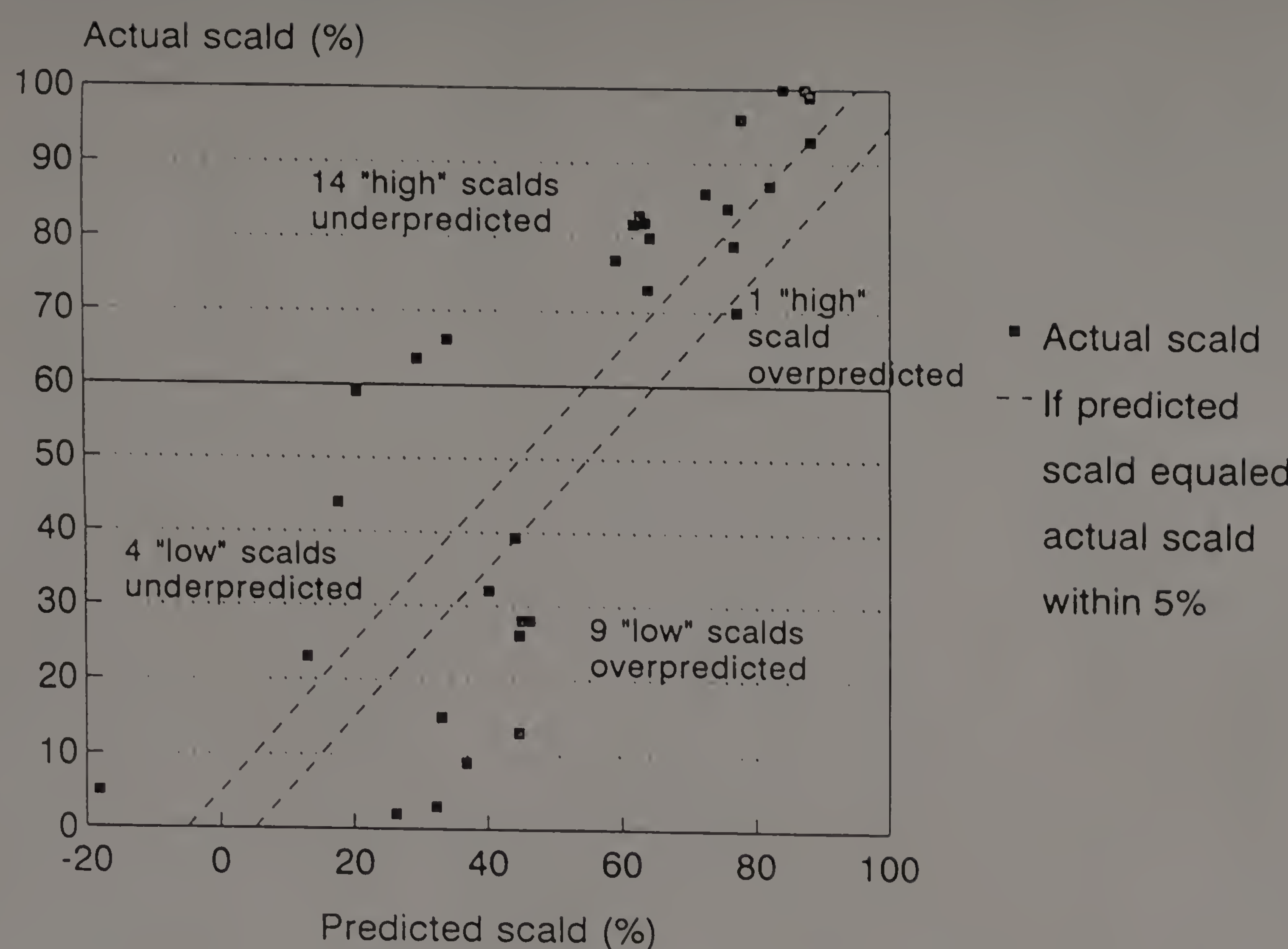

Figure 4.6 Effectiveness of the equation % Scald = 135 - 1.6(harvest day after Sept 1) - 0.42(number of days at or below 5°C) - 0.82(average daily mm rain from 02 or 03 Sept to harvest) - 49(average daily light score from 02 or 03 Sept to harvest) - 4.0(harvest starch score) in predicting scald on HRC-grown 'Cortland' apples in a reserved subsample of the data from the years 1987-1993.

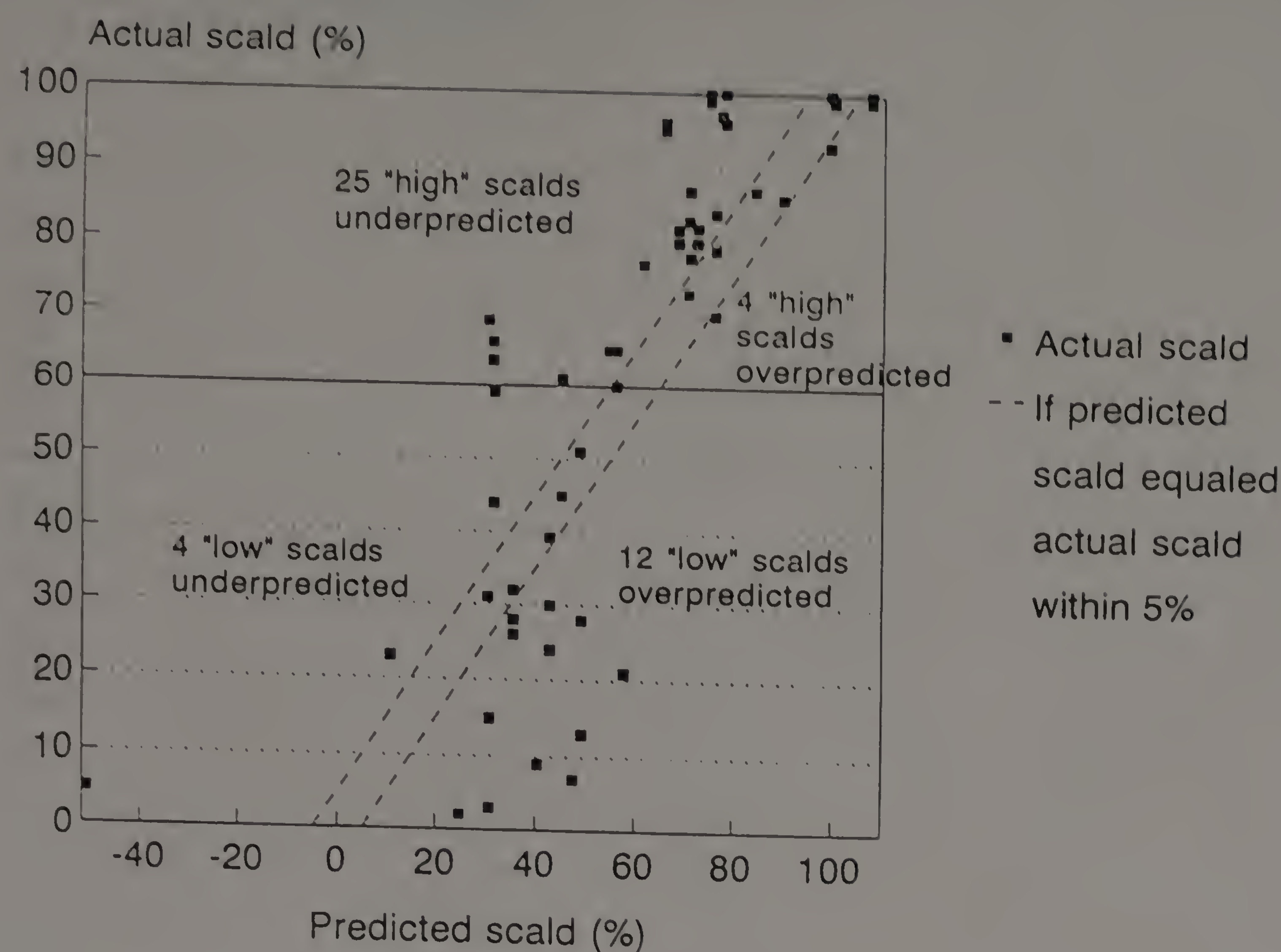

Figure 4.7 Effectiveness of the equation % Scald = 138 - 1.2(harvest day after Sept 1) - 2.7(days at orbelow 8°C) - 0.027(average daily mm rain from 02 or 03 Sept to harvest) - 45(avg daily light score from 02 or 03 Sept to harvest) in predicting scald on HRC-grown 'Cortland' apples in a reserved subsample of the data from the years 1985-1993.

Table 4.12 Equations relating scald on HRC-grown 'Cortland' apples to various independent variables including number of preharvest days with temperature at or below 8°C. Equations are of the general form: Percent scald= $B_0 + B_1DA^z + B_2D8^y + B_3ST^x + B_4RAIN^w + B_5SUN^v$. N=210.

Form of percent scald (scald) used in equation	Form of independent variables (var) used in equation		Variables (var)						R^2	D-W d
			CONST	DA^z	$D8^y$	ST^x	$RAIN^w$	SUN^v		
scald	var	coef (B_x)	141	-1.6	-0.60	-3.7	+0.40	-55	0.63	1.09
		t	9.94	-2.92	-0.93	-2.28	+0.59	-3.14		
exp(scald/100)	var	coef (B_x)	3.3	-0.029	-0.0043	-0.079	+0.0096	-0.85	0.64	1.14
		t	13.21	-3.06	-0.38	-2.77	+0.81	-2.77		
ln(scald+1)	var	coef (B_x)	6.0	-0.033	-0.062	-0.0027	+0.022	-1.8	0.57	0.86
		t	13.58	-1.95	-3.08	-0.05	+1.05	-3.34		
scald	ln(var)[u]	coef (B_x)	187	-14	-19	-18	+6.4	-94	0.70	1.06
		t	8.83	-2.27	-4.58	-6.00	+2.31	-3.70		
scald	sqrt(var)	coef (B_x)	224	-10	-9.7	-16	+2.4	-94	0.69	1.10
		t	8.67	-2.46	-2.84	-3.51	+1.04	-3.73		
exp(scald/100)	ln(var)[u]	coef (B_x)	4.0	-0.22	-0.34	-0.36	+0.11	-1.4	0.73	1.21
		t	11.23	-2.10	-4.84	-6.91	+2.39	-3.36		
exp(scald/100)	sqrt(var)	coef (B_x)	4.7	-0.17	-0.17	-0.33	+0.044	-1.4	0.70	1.19
		t	10.40	-2.32	-2.79	-4.23	+1.11	-3.30		

[z] DA=Harvest date as days after 01 September.
[y] D8=Number of preharvest days with temperature at or below 8°C.
[x] ST=Starch score at harvest.
[w] RAIN=Average daily mm rain from 01 September to harvest.
[v] SUN=Average daily light score from 01 September to harvest.
[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.13 Equations relating scald on HRC-grown 'Cortland' apples to various independent variables including number of preharvest days with temperature at or below 6°C. Equations are of the general form: Percent scald= $B_0 + B_1DA^z + B_2D6^y + B_3ST^x + B_4RAIN^w + B_5SUN^v$. N=210.

Form of percent scald (scald) used in equation	Form of independent variables (var) used in equation		CONST	Independent variables (var)					R^2	D-W d
				DA^z	$D6^y$	ST^x	$RAIN^w$	SUN^v		
scald	var	coef (B_x)	194	-4.1	3.7	-1.0	+0.43	-101	0.68	1.26
		t	13.97	-8.66	5.44	-0.67	+0.69	-6.21		
exp(scald/100)	var	coef (B_x)	4.1	-0.067	0.062	-0.039	-0.010	-1.5	0.68	1.29
		t	16.71	-8.02	5.13	-1.48	-0.94	-5.39		
exp(scald/100)	ln(var)[u]	coef (B_x)	4.3	-0.38	-0.17	-0.33	+0.066	-1.9	0.72	1.29
		t	12.19	-4.28	-3.85	-6.07	+1.35	-4.60		
exp(scald/100)	sqrt(var)	coef (B_x)	5.1	-0.27	-0.054	-0.30	+0.028	-1.9	0.69	1.25
		t	11.89	-4.54	-1.31	-3.87	+0.69	-4.59		

[z] DA=Harvest date as days after 01 September.
[y] D6=Number of preharvest days with temperature at or below 6°C.
[x] ST=Starch score at harvest.
[w] RAIN=Average daily mm rain from 01 September to harvest.
[v] SUN=Average daily light score from 01 September to harvest.
[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.14 Equations relating scald on HRC-grown 'Cortland' apples to various independent variables including number of preharvest days with temperature at or below 10°C. Equations are of the general form: Percent scald= $B_0 + B_1DA^z + B_2D10^y + B_3ST^x + B_4RAIN^w + B_5SUN^v$. N=210.

Form of percent scald (scald) used in equation	Form of independent variables (var) used in equation		CONST	Independent variables (var)					R^2	D-W d
				DA[z]	D10[y]	ST[x]	RAIN[w]	SUN[v]		
scald	var	coef (B_x)	145	-1.6	-0.41	-3.8	+0.37	-59	0.63	1.09
		t	12.10	-3.86	-1.29	-2.40	+0.56	-3.72		
exp(scald/100)	var	coef (B_x)	3.3	-0.026	-0.0064	-0.085	+0.0094	-0.85	0.64	1.14
		t	15.62	-3.56	-1.13	-3.03	+0.80	-3.06		
exp(scald/100)	ln(var)[u]	coef (B_x)	4.6	-0.38	-0.21	-0.39	+0.12	-1.9	0.71	1.26
		t	13.85	-4.07	-3.27	-7.51	+2.37	-4.56		
exp(scald/100)	sqrt(var)	coef (B_x)	5.2	-0.24	-0.087	-0.33	+0.041	-1.8	0.70	1.21
		t	13.30	-4.33	-2.25	-4.16	+1.02	-4.54		

[z] DA=Harvest date as days after 01 September.
[y] D10=Number of preharvest days with temperature at or below 10°C.
[x] ST=Starch score at harvest.
[w] RAIN=Average daily mm rain from 01 September to harvest.
[v] SUN=Average daily light score from 01 September to harvest.
[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.15 Equations relating scald on HRC-grown 'Cortland' apples to various independent variables including number of preharvest days with temperature at or below 12°C. Equations are of the general form: Percent scald= $B_0 + B_1DA^z + B_2D12^y + B_3ST^x + B_4RAIN^w + B_5SUN^v$. N=210.

Form of percent scald (scald) used in equation	Form of independent variables (var) used in equation		CONST	Independent variables (var)					R^2	D-W d
				DA^z	$D12^y$	ST^x	$RAIN^w$	SUN^v		
scald	var	coef (B_x)	148	-1.8	-0.21	-3.6	+0.40	-61	0.63	1.10
		t	2.572	-4.72	-10.90	-2.26	+0.60	-3.93		
exp(scald/100)	var	coef (B_x)	3.3	-0.030	-0.0020	-0.079	+0.0097	-0.90	0.64	1.15
		t	16.12	-4.52	-0.50	-2.83	+0.83	-3.26		
exp(scald/100)	ln(var)[u]	coef (B_x)	5.0	-0.48	-0.16	-0.39	+0.10	-2.2	0.70	1.30
		t	14.78	-5.52	-2.18	-7.41	+2.09	-5.21		
exp(scald/100)	sqrt(var)	coef (B_x)	5.4	-0.29	-0.041	-0.31	+0.036	-2.0	0.69	1.23
		t	13.99	-5.85	-1.20	-3.91	+0.90	-4.97		

[z] DA=Harvest date as days after 01 September.
[y] D12=Number of preharvest days with temperature at or below 12°C.
[x] ST=Starch score at harvest.
[w] RAIN=Average daily mm rain from 01 September to harvest.
[v] SUN=Average daily light score from 01 September to harvest.
[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.16 A compilation of R^2 values and Durbin-Watson d values of equations relating scald on HRC-grown 'Cortland' apples to various independent variables. Equations are of the general form: Percent scald (scald)= $B_0 + B_1DA^z + B_2Dx^y + B_3RAIN^x + B_4SUN^w + B_5ST^v$.

Low temperature → variable		No low temperature variable						6		8		10		12	
Dependent variable	Form of independent variables	No starch data n=358		No starch data n=210		Starch data included n=210									
		R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d
scald	var	0.56	1.04	0.62	1.07	0.63	1.11	0.68	1.26	0.63	1.09	0.63	1.09	0.63	1.10
$e^{(scald/100)}$	var	0.56	1.06	0.62	1.07	0.64	1.15	0.68	1.29	0.64	1.14	0.64	1.14	0.64	1.15
ln(scald+1)	var	0.46	0.71	0.55	0.81	0.55	0.83	0.58	0.86	0.57	0.86	0.57	0.83	0.56	0.84
scald	ln(var)^u	0.45	0.87	0.60	1.06	0.67	1.17	0.68	1.13	0.70	1.06	0.68	1.10	0.68	1.15
scald	sqrt(var)	0.54	1.01	0.66	1.12	0.67	1.16	0.67	1.15	0.69	1.10	0.68	1.12	0.68	1.14
$e^{(scald/100)}$	ln(var)^u	0.46	0.92	0.62	1.13	0.70	1.32	0.72	1.29	0.73	1.21	0.71	1.26	0.70	1.30
$e^{(scald/100)}$	sqrt(var)	0.55	1.05	0.67	1.16	0.69	1.26	0.69	1.25	0.70	1.19	0.70	1.21	0.69	1.23

^{z} DA=Harvest date as days after 01 September.
^{y} Dx=Number of preharvest days with temperature at or below x°C.
^{x} RAIN=Average daily mm rain from 01 September to harvest.
^{w} SUN=Average daily light score from 01 September to harvest.
^{v} ST=Starch score at harvest.
^{u} If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.17 A compilation of R^2 values and Durbin-Watson d values of equations relating scald on HRC-grown 'Cortland' apples to various independent variables, including pre-harvest high temperatures completely offsetting pre-harvest low temperatures. Equations are of the general form: Percent scald (Scald) = $B_0 + B_1DA^z + B_2DxD^y + B_3RAIN^x + B_4SUN^w + B_5ST^v$.

Dependent variable	Form of independent variables	Starch excluded from equations n=358								Starch included in equations n=210							
		x=6		x=8		x=10		x=12		x=6		x=8		x=10		x=12	
		R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d
scald	var	0.57	0.92	0.61	0.94	0.62	0.92	0.63	0.92	0.69	1.24	0.63	1.07	0.63	1.06	0.63	1.06
$e^{(scald/100)}$	var	0.58	0.94	0.62	0.97	0.63	0.97	0.64	0.97	0.69	1.24	0.64	1.10	0.64	1.09	0.64	1.09
scald	ln(var)[u]	0.61	0.89	0.65	0.76	0.63	0.73	0.64	0.78	0.69	1.02	0.70	0.89	0.69	0.93	0.69	0.98
scald	sqrt(var)	0.63	0.92	0.67	0.86	0.66	0.83	0.66	0.86	0.67	1.09	0.69	1.01	0.69	1.03	0.68	1.06
$e^{(scald/100)}$	ln(var)[u]	0.63	0.96	0.69	0.88	0.67	0.84	0.67	0.90	0.71	1.14	0.74	1.03	0.73	1.06	0.72	1.11
$e^{(scald/100)}$	sqrt(var)	0.64	0.97	0.69	0.96	0.69	0.94	0.69	0.96	0.69	1.15	0.71	1.11	0.71	1.11	0.70	1.14

[z] DA=Harvest date as days after 01 September.
[y] DxD=Number of preharvest days with temperature at or below x°C, restart count if temperature reaches 30°C.
[x] RAIN=Average daily mm rain from 01 September to harvest.
[w] SUN=Average daily light score from 01 September to harvest.
[v] ST=Starch score at harvest.
[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.18 A compilation of R^2 values and Durbin-Watson d values of equations relating scald on HRC-grown 'Cortland' apples to various independent variables, including pre-harvest temperatures at or above 30°C offsetting pre-harvest low temperatures by one day for each day of high temperature. Equations are of the general form: Percent scald (Scald) = $B_0 + B_1DA^z + B_2DxH^y + B_3RAIN^x + B_4SUN^w + B_5ST^v$.

Dependent variable	Form of independent variables	Starch excluded from equations n=358								Starch included in equations n=210							
		x=6		x=8		x=10		x=12		x=6		x=8		x=10		x=12	
		R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d
scald	var	0.56	0.93	0.56	0.93	0.56	0.93	0.56	0.93	0.70	1.21	0.65	1.08	0.64	1.08	0.64	1.06
$e^{(scald/100)}$	var	0.56	0.95	0.57	0.95	0.57	0.95	0.56	0.95	0.71	1.25	0.67	1.13	0.65	1.12	0.64	1.10
scald	ln(var)[u]	0.51	0.85	0.51	0.86	0.51	0.83	0.49	0.84	0.69	1.18	0.67	1.09	0.67	1.09	0.67	1.09
scald	sqrt(var)	0.56	0.91	0.56	0.92	0.56	0.90	0.55	0.91	0.72	1.26	0.69	1.12	0.67	1.11	0.67	1.10
$e^{(scald/100)}$	ln(var)[u]	0.53	0.91	0.52	0.92	0.52	0.88	0.50	0.88	0.71	1.30	0.70	1.22	0.70	1.21	0.70	1.21
$e^{(scald/100)}$	sqrt(var)	0.57	0.96	0.57	0.96	0.57	0.94	0.56	0.95	0.73	1.31	0.70	1.20	0.69	1.18	0.69	1.17

[z] DA=Harvest date as days after 01 September.
[y] DxH=Number of preharvest days with temperature at or below x°C, subtract one from count for each day temperature reaches 30°C or more. DxH < 0 is considered to be 0.
[x] RAIN=Average daily mm rain from 01 September to harvest.
[w] SUN=Average daily light score from 01 September to harvest.
[v] ST=Starch score at harvest.
[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.19 A compilation of R^2 values and Durbin-Watson d values of equations relating scald on HRC-grown 'Cortland' apples to various independent variables, including pre-harvest temperatures at or above 30°C offsetting pre-harvest low temperatures by two days for each day of high temperature. Equations are of the general form: Percent scald (Scald) = $B_0 + B_1DA^z + B_2DxHH^y + B_3RAIN^x + B_4SUN^w + B_5ST^v$.

Dependent variable	Form of independent variables	Starch excluded from equations n=358								Starch included in equations n=210							
		x=6		x=8		x=10		x=12		x=6		x=8		x=10		x=12	
		R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d
scald	var	0.57	0.93	0.58	0.95	0.57	0.94	0.56	0.93	0.64	1.05	0.63	1.05	0.64	1.06	0.64	1.06
$e^{(scald/100)}$	var	0.57	0.95	0.58	0.96	0.58	0.96	0.57	0.95	0.66	1.10	0.64	1.09	0.64	1.10	0.65	1.10
scald	ln(var)[u]	0.52	0.88	0.54	0.92	0.50	0.85	0.49	0.83	0.67	1.09	0.68	1.11	0.67	1.10	0.67	1.09
scald	sqrt(var)	0.57	0.93	0.58	0.95	0.56	0.91	0.55	0.91	0.68	1.10	0.67	1.10	0.68	1.12	0.68	1.12
$e^{(scald/100)}$	ln(var)[u]	0.53	0.93	0.55	0.97	0.52	0.90	0.51	0.88	0.70	1.22	0.70	1.21	0.70	1.22	0.70	1.22
$e^{(scald/100)}$	sqrt(var)	0.59	0.97	0.59	1.00	0.58	0.96	0.56	0.95	0.70	1.20	0.69	1.17	0.69	1.19	0.70	1.19

[z] DA=Harvest date as days after 01 September.

[y] DxHH=Number of preharvest days with temperature at or below x°C, subtract two from count for each day temperature reaches 30°C or more. DxHH < 0 is considered to be 0.

[x] RAIN=Average daily mm rain from 01 September to harvest.

[w] SUN=Average daily light score from 01 September to harvest.

[v] ST=Starch score at harvest.

[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.20 Logit prediction equations to test ability to identify especially scald-resistant 'Cortland' apples. Equations n=300, with 252 observations at 0, and 48 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	% cases correctly placed	NSI[z]
A	-12	+0.16 (3.56)	+0.067 (0.09)	-0.078 (-0.64)	+10 (3.86)	84	0.294
B	-12	-0.022 (-0.46)	+0.56 (4.87)	-0.13 (-1.02)	+11 (4.05)	91	0.416
C	-24	+1.3 (2.49)	+1.0 (1.84)	-0.048 (-0.09)	+19 (3.95)	89	0.331
D	-28	-0.37 (-0.73)	+4.2 (4.95)	-0.18 (-0.35)	+21 (4.29)	91	0.453

A. Predict Good[y] if Index: $B_0 + B_1DA^x + B_2D6^w + B_3RAIN^v + B_4SUN^u >= 0$

B. Predict Good[y] if Index: $B_0 + B_1DA^x + B_2D8^t + B_3RAIN^v + B_4SUN^u >= 0$

C. Predict Good[y] if Index: $B_0 + B_1 1(sqrt^s DA^x) + B_2(sqrtD6^w) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) >= 0$

D. Predict Good[y] if Index: $B_0 + B_1 1(sqrt^s DA^x) + B_2(sqrtD8^t) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) >= 0$

Test of Equation A n=58	No. of cases actually: Not Good(0)	No. of cases actually: Good (1)
Not predicted Good (I<0)	46	5
Predicted Good (I≥0)	5	2

Test of Equation B	No. of cases actually: Not Good(0)	No. of cases actually: Good (1)
Not predicted Good (I<0)	50	2
Predicted Good (I≥0)	1	5

Test of Equation C	No. of cases actually: Not Good(0)	No. of cases actually: Good (1)
Not predicted Good (I<0)	48	4
Predicted Good (I≥0)	3	3

Test of Equation D	No. of cases actually: Not Good(0)	No. of cases actually: Good (1)
Not predicted Good (I<0)	50	4
Predicted Good (I≥0)	1	3

[z]NSI = Normalized Success Index.
[y]Good refers to lots of fruit in which less than 20% of fruit scalded.
[x]DA = harvest date as Julian day - 243.
[w]D6 = Number of preharvest days with temperatures at or below 6°C.
[v]RAIN = Average daily mm rain from 01 September to harvest.
[u]SUN = Average daily light score from 01 September to harvest.
[t]D8 = Number of preharvest days with temperatures at or below 8°C.
[s]sqrt = square root.

Table 4.21 Logit prediction equations to test ability to identify especially scald-susceptible 'Cortland' apples. Equations: n=300, with 155 observations at 0, and 145 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	% cases correctly placed	NSI[z]
A	+5.8	-0.14 (-4.08)	-0.19 (-2.44)	-0.079 (-0.99)	-1.8 (-0.94)	83	0.462
B	+4.7	-0.012 (-0.31)	-0.55 (-5.56)	-0.023 (-0.29)	+0.85 (0.37)	90	0.558
C	+11	-1.1 (-3.45)	-1.1 (-3.45)	-0.51 (-1.51)	-2.1 (-0.73)	83	0.481
D	+9.0	-0.031 (-0.08)	-3.5 (-5.79)	-0.055 (-0.17)	+2.0 (0.61)	90	0.575

A. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2D6^w + B_3RAIN^v + B_4SUN^u >= 0$

B. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2D8^t + B_3RAIN^v + B_4SUN^u >= 0$

C. Predict Bad[y] if Index: $B_0 + B_1(sqrt^s DA^x) + B_2(sqrtD6^w) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) >= 0$

D. Predict Bad[y] if Index: $B_0 + B_1(sqrtDA^x) + B_2(sqrtD8^t) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) >= 0$

Test of Equation A n=58	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	22	8
Predicted Bad (I>=0)	1	27

Test of Equation B	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	23	6
Predicted Bad (I>=0)	0	29

Test of Equation C	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	22	8
Predicted Bad (I>=0)	1	27

Test of Equation D	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	23	6
Predicted Bad (I>=0)	0	29

[z] NSI = Normalized Success Index.
[y] Bad refers to lots of fruit in which over 60% of fruit scalded.
[x] DA = harvest date as Julian day - 243.
[w] D6 = Number of preharvest days with temperatures at or below 6°C.
[v] RAIN = Average daily mm rain from 01 September to harvest.
[u] SUN = Average daily light score from 01 September to harvest.
[t] D8 = Number of preharvest days with temperatures at or below 8°C.
[s] sqrt = square root.

Table 4.22 Logit prediction equations to test ability to identify especially scald-resistant 'Cortland' apples. Equations n=171, with 144 observations at 0, and 27 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	% cases correctly placed	NSI[z]
A	-30	+0.84 (3.89)	-0.85 (-3.13)	+0.12 (0.74)	+27 (3.66)	-1.1 (-2.53)	87	0.409
B	-9.7	+0.055 (0.47)	+0.30 (1.83)	-0.11 (-0.73)	+7.8 (2.07)	-0.10 (-0.28)	85	0.320
C	-43	+5.3 (3.53)	-2.0 (-2.48)	-0.089 (-0.15)	+30 (3.51)	-1.5 (-1.13)	88	0.367
D	-23	+0.38 (0.35)	+2.3 (2.06)	-0.16 (-0.26)	+18 (2.66)	-0.048 (-0.04)	87	0.350

A. Predict Good[y] if Index: $B_0 + B_1DA^x + B_2D6^w + B_3RAIN^v + B_4SUN^u + B_5ST^t >= 0$

B. Predict Good[y] if Index: $B_0 + B_1DA^x + B_2D8^s + B_3RAIN^v + B_4SUN^u + B_5ST^t >= 0$

C. Predict Good[y] if Index: $B_0 + B_1(sqrt^rDA^x) + B_2(sqrtD6^w) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) + B_5(sqrtST^t) >= 0$

D. Predict Good[y] if Index: $B_0 + B_1(sqrt^rDA^x) + B_2(sqrtD8^s) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) + B_5(sqrtST^t) >= 0$

Test of Equation A n=39	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	27	3
Predicted Good (I≥0)	3	6

Test of Equation B	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	29	6
Predicted Good (I≥0)	1	3

Test of Equation C	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	27	3
Predicted Good (I≥0)	3	6

Test of Equation D	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	29	3
Predicted Good (I≥0)	1	6

[z] NSI = Normalized Success Index.
[y] Good refers to lots of fruit in which less than 20% of fruit scalded.
[x] DA = harvest date as Julian day - 243.
[w] D6 = Number of preharvest days with temperatures at or below 6°C.
[v] RAIN = Average daily mm rain from 01 September to harvest.
[u] SUN = Average daily light score from 01 September to harvest.
[t] ST = Harvest starch score.
[s] D8 = Number of preharvest days with temperatures at or below 8°C.
[r] sqrt = square root.

Table 4.23 Logit prediction equations to test ability to identify especially scald-susceptible 'Cortland' apples. Equations: N=171, with 94 observations at 0, and 77 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	Pct cases correctly placed	NSI[z]
A	+14	-0.44 (-4.04)	+0.53 (4.05)	+0.044 (0.35)	-9.2 (-2.38)	-0.33 (-1.22)	81	0.520
B	+4.1	-0.043 (-0.47)	-0.095 (-0.71)	+0.094 (0.86)	-0.80 (-0.27)	-0.65 (-2.64)	85	0.473
C	+18	-2.0 (-2.42)	+0.49 (1.10)	+0.19 (0.43)	-8.6 (-1.74)	-1.7 (-2.15)	85	0.493
D	+11	-0.42 (-0.51)	-0.086 (-1.17)	+0.23 (0.53)	-4.0 (-0.83)	-2.1 (-2.69)	86	0.500

A. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2D6^w + B_3RAIN^v + B_4SUN^u + B_5ST^t >= 0$

B. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2D8^s + B_3RAIN^v + B_4SUN^u + B_5ST^t >= 0$

C. Predict Bad[y] if Index: $B_0 + B_1(sqrt^r DA^x) + B_2(sqrtD6^w) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) + B_5(sqrtST^t) >= 0$

D. Predict Bad[y] if Index: $B_0 + B_1(sqrt^r DA^x) + B_2(sqrtD8^s) + B_3(sqrtRAIN^v) + B_4(sqrtSUN^u) + B_5(sqrtST^t) >= 0$

Test of Equation A n=39	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	19	2
Predicted Bad (I≥0)	3	15

Test of Equation B	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	21	2
Predicted Bad (I≥0)	1	15

Test of Equation C	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	20	2
Predicted Bad (I≥0)	2	15

Test of Equation D	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	21	2
Predicted Bad (I≥0)	1	15

[z] NSI = Normalized Success Index.
[y] Bad refers to lots of fruit in which over 60% of fruit scalded.
[x] DA = harvest date as Julian day - 243.
[w] D6 = Number of preharvest days with temperatures at or below 6°C.
[v] RAIN = Average daily mm rain from 01 September to harvest.
[u] SUN = Average daily light score from 01 September to harvest.
[t] ST = Harvest starch score.
[s] D8 = Number of preharvest days with temperatures at or below 8°C.
[r] sqrt = square root.

Table 4.24 Correlations of poststorage scald incidence on HRC-grown 'Cortland' apples with preharvest cool temperatures.

Variable	Year	N	Minimum	Maximum	Mean	Corr w/ scald
Preharvest hours at or below 6°C	all	225	0	396	45	-0.50
	1988	48	14	39	26	-0.84
	1990	51	0	37	25	-0.82
	1991	60	3	134	57	-0.85
	1992	31	16	396	98	-0.73
	1993	35	0	88	33	-0.53
Preharvest hours at or below 8°C	all	225	0	538	82	-0.58
	1988	48	44	106	70	-0.80
	1990	51	0	97	59	-0.89
	1991	60	7	201	86	-0.85
	1992	31	34	538	141	-0.72
	1993	35	8	155	70	-0.62
Preharvest hours at or below 10°C	all	225	0	702	139	-0.64
	1988	48	80	199	134	-0.86
	1990	51	0	158	97	-0.88
	1991	60	15	301	139	-0.87
	1992	31	73	702	222	-0.76
	1993	35	19	261	134	-0.69
Preharvest hours at or below 12°C	all	225	7	867	218	-0.71
	1988	48	156	336	238	-0.86
	1990	51	7	255	159	-0.87
	1991	60	23	409	203	-0.88
	1992	31	139	867	324	-0.78
	1993	35	34	370	212	-0.74

Table 4.25 Correlations among variables relating to 'Cortland' fruit grown at HRC from 1988 to 1993. N=173.

DA[z]	+0.85[y]						
DAFB[x]	+0.89	+0.85					
Hours[w] ≤ 6°C	+0.59	+0.75	+0.60				
Hours[w] ≤ 8°C	+0.64	+0.82	+0.63	+0.99			
Hours[w] ≤ 10°C	+0.68	+0.87	+0.65	+0.96	+0.99		
Hours[w] ≤ 12°C	+0.69	+0.89	+0.63	+0.92	+0.96	+0.99	
SCALD	-0.68	-0.72	-0.58	-0.55	-0.60	-0.65	-0.70
	Starch[v]	Day	DAFB	Hours ≤ 6°C	Hours ≤ 8°C	Hours ≤ 10°C	Hours ≤ 12°C

[z] DA = harvest date as days after 01 September.
[y] All correlation coefficients are significant at P ≤ 0.01.
[x] DAFB = harvest date as days after full bloom.
[w] Hours = number of preharvest hours with stated recorded temperature.
[v] Starch = starch score at harvest.

Table 4.26 Correlations among variables relating to 'Cortland' fruit grown at HRC from 1988 to 1993. N=225. Note that this table includes 52 cases excluded from Table 25 above for which no starch scores were available.

DAFB[z]	+0.86[y]					
Hours[x] ≤ 6°C	+0.72	+0.60				
Hours[x] ≤ 8°C	+0.81	+0.63	+0.98			
Hours[x] ≤ 10°C	+0.86	+0.65	+0.95	+0.99		
Hours[x] ≤ 12°C	+0.88	+0.62	+0.89	+0.95	+0.99	
SCALD	-0.70	-0.52	-0.50	-0.58	-0.64	-0.71
	DA[w]	DAFB	Hours ≤ 6°C	Hours ≤ 8°C	Hours ≤ 10°C	Hours ≤ 12°C

[z] DAFB = harvest date as days after full bloom.
[y] All correlation coefficients are significant at P ≤ 0.01.
[x] Hours = number of preharvest hours with stated recorded temperature.
[w] DA = harvest date as days after 01 September.

Table 4.27 Correlations between number of preharvest hours at or below 6°C, 8°C, 10°C, or 12°C and preharvest rainfall (RAIN[z]) and light (SUN[y]) scores.

Variable	Year	N	Corr w/RAIN	Corr w/ SUN
Preharvest hours at or below 6°C	all	225	0.11	-0.22*[x]
	1988	48	-0.91**	-0.87**
	1990	51	+0.38**	+0.44**
	1991	60	+0.47**	-0.55**
	1992	31	-0.02	+0.28
	1993	35	-0.48**	+0.00
Preharvest hours at or below 8°C	all	225	0.07	-0.17*
	1988	48	-0.87**	-0.87**
	1990	51	+0.35*	+0.48**
	1991	60	+0.47**	-0.56**
	1992	31	-0.01	+0.27
	1993	35	-0.38*	-0.11
Preharvest hours at or below 10°C	all	225	0.09	-0.18*
	1988	48	-0.93**	-0.79**
	1990	51	+0.38**	+0.47**
	1991	60	+0.53**	-0.61**
	1992	31	-0.02	+0.32
	1993	35	-0.29	-0.21
Preharvest hours at or below 12°C	all	225	0.06	-0.16*
	1988	48	-0.94**	-0.74**
	1990	51	+0.37**	+0.47**
	1991	60	+0.58**	-0.65**
	1992	31	-0.06	+0.36*
	1993	35	-0.22	-0.32

[z] RAIN = Average daily mm rainfall from 02 or 03 September to harvest.
[y] SUN = Average daily light score from 02 or 03 September to harvest.
[x] *=significant at P = 0.05, **= significant at P = 0.01.

Table 4.28 Some ordinary least squares equations relating poststorage scald on HRC-grown 'Cortland' apples to a variety of variables and data sets.

Equation #	N	Percent scald =	R^2	Durbin-Watson d
1	173	101 - 0.91*DA[z] - 0.045*H10[y] - 4.3*ST[x] t= 18.79[**w] -2.28[*] -1.62[ns] -2.71[**]	0.54	1.05
2	173	96 - 0.18*DA - 0.083*H12[t] - 5.4*ST t= 19.08[**] -0.42[ns] -3.48[**] -3.40[**]	0.57	1.11
3	173	151 - 2.2*DA + 0.013*H10 - 1.7*ST + 0.065*RAIN[v] - 69*SUN[u] t= 10.83[**] -4.59[**] +0.43[ns] -0.95[ns] +0.08[ns] -3.95[**]	0.59	1.06
4	173	163 - 1.4*DA - 0.063*H12 + 0.64*ST - 4.0*RAIN - 103*SUN t= 14.75[**] -3.33[**] -2.86[**] 0.37[ns] -4.94[**] -6.17[**]	0.67	1.21
5	225	103 - 1.6*DA - 0.049*H10 t= 20.76[**] -6.02[**] -1.82[*]	0.50	0.86
6	225	99 - 0.98*DA - 0.092*H12 t= 21.65[**] -3.53[**] -4.18[**]	0.53	0.95
7	225	170 - 2.4*DA - 0.00030*H10 - 0.85*RAIN - 100*SUN t= 17.69[**] -9.04[**] -0.01[ns] -1.29[ns] -7.92[**]	0.61	0.94
8	225	162 - 1.8*DA - 0.046*H12 - 1.2*RAIN - 93*SUN t= 16.90[**] -6.11[**] -2.07[*] -1.79[*] -7.28[**]	0.62	0.99

[z] DA = Harvest date as days after 01 September.
[y] H10 = Number of preharvest hours of temperatures recorded at or below 10°C.
[x] ST = Starch score at harvest.
[w] [ns]= not significant at P=0.05, [*]= significant at $P \leq 0.05$, [**]= significant at $P \leq 0.01$.
[v] RAIN = Average daily mm rainfall from 02 or 03 Sept to harvest.
[u] SUN = Average daily light score from 02 or 03 Sept to harvest.
[t] H12 = Number of preharvest hours of temperatures recorded at or below 12°C.

Table 4.29 A compilation of R^2 values and Durbin-Watson d values of equations relating scald on HRC-grown 'Cortland' apples to various independent variables, including low temperature variables expressed as number of preharvest hours at or below a number of different temperatures. Equations are of the general form: Percent scald (scald)= Constant+ $(B1*DA^z)$+ $(B2*Hx^y)$+ $(B3*RAIN^x)$+ $(B4*SUN^w)$+ $(B5*ST^v)$.

Low temperature variable →		No low temperature variable						x=6		x=8		x=10		x=12	
Dependent variable	Form of independent variables	No starch data n=225		No starch data n=173		Starch data included n=173									
		R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d	R^2	d
scald	var	0.61	0.94	0.59	1.06	0.59	1.07	0.59	1.05	0.60	1.05	0.59	1.06	0.60	1.10
scald	ln(var)[u]	0.63	0.88	0.58	1.05	0.63	1.10	0.68	1.04	0.67	1.07	0.66	1.06	0.68	0.97
scald	sqrt(var)	0.66	0.89	0.64	1.07	0.64	1.08	0.65	1.15	0.65	1.12	0.65	1.11	0.67	1.09
$e^{(scald/100)}$	var	0.62	0.98	0.59	1.08	0.60	1.11	0.60	1.09	0.61	1.09	0.60	1.12	0.60	1.12
$e^{(scald/100)}$	ln(var)[u]	0.65	0.98	0.60	1.14	0.65	1.20	0.71	1.18	0.70	1.21	0.69	1.20	0.72	1.11
$e^{(scald/100)}$	sqrt(var)	0.68	0.98	0.65	1.14	0.65	1.15	0.66	1.19	0.66	1.17	0.67	1.18	0.68	1.17

[z] DA=Harvest date as days after 01 September.

[y] Hx=Number of preharvest hours with temperature at or below x°C.

[x] RAIN=Average daily mm rain from 02 or 03 September to harvest.

[w] SUN=Average daily light score from 02 or 03 September to harvest.

[v] ST=Starch score at harvest.

[u] If the value of a variable was sometimes zero, (var+1) was used instead of (var).

Table 4.30 Logit prediction equations to test ability to identify especially scald-susceptible 'Cortland' apples. Equations: N=152, with 91 observations at 0, and 61 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	% of cases correctly placed	NSI[z]
A	+7.0	-0.12 (-1.50)	+0.00041 (0.05)	-0.00019 (-0.00)	-4.9 (-1.75)	-0.43 (-1.68)	83	0.425
B	+7.0	-0.12 (-2.31)	-0.00020 (-0.12)	-0.0023 (-0.02)	-4.8 (-1.82)	-0.44 (-1.69)	83	0.425
C	+17	-1.6 (-0.79)	-1.2 (-1.13)	-0.15 (-0.24)	-13 (-2.38)	-1.5 (-2.20)	86	0.480
D	+18	-1.2 (-0.57)	-1.4 (-1.27)	-0.17 (-0.26)	-12 (-2.32)	-1.7 (-2.39)	86	0.481

A. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2H10^w + B_3RAIN^v + B_4SUN^u + B_5ST^t >= 0$

B. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2H12^s + B_3RAIN^v + B_4SUN^u + B_5ST^t >= 0$

C. Predict Bad[y] if Index: $B_0 + B_1(\ln DA^x) + B_2(\ln H10^w) + B_3(\ln RAIN^v) + B_4(\ln SUN^u) + B_5(\ln ST^t) >= 0$

D. Predict Bad[y] if Index: $B_0 + B_1(\ln DA^x) + B_2(\ln H12^s) + B_3(\ln RAIN^v) + B_4(\ln SUN^u) + B_5(\ln ST^t) >= 0$

Test of Equation A n=21	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	8	1
Predicted Bad (I≥0)	4	8

Test of Equation B	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	8	1
Predicted Bad (I≥0)	4	8

Test of Equation C	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	9	1
Predicted Bad (I≥0)	3	8

Test of Equation D	No. of cases actually: Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	8	1
Predicted Bad (I≥0)	4	8

[z] NSI = Normalized Success Index.
[y] Bad refers to lots of fruit in which over 60% of fruit scalded.
[x] DA = harvest date as Julian day - 243.
[w] H10 = Number of preharvest hours with temperatures at or below 10°C.
[v] RAIN = Average daily mm rain from 02 or 03 September to harvest.
[u] SUN = Average daily light score from 02 or 03 September to harvest.
[t] ST = Harvest starch score.
[s] H12 = Number of preharvest hours with temperatures at or below 12°C.

Table 4.31 Logit prediction equations to test ability to identify especially scald-susceptible 'Cortland' apples. Equations: n=195, with 115 observations at 0, and 80 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	Percent of cases correctly placed	NSI[z]
A	+9.6	-0.20 (-3.20)	-0.0013 (-0.17)	-0.13 (-1.36)	-8.0 (-3.43)	86	0.447
B	+9.7	-0.21 (-7.02)	-0.00040 (-0.26)	-0.13 (-1.35)	-8.2 (-3.74)	86	0.447
C	+25	-4.4 (-2.56)	-0.85 (-0.89)	-0.63 (-1.26)	-16 (-3.31)	86	0.488
D	+26	-5.0 (-3.20)	-0.57 (-0.59)	-0.65 (-1.29)	-16 (-3.41)	86	0.486

A. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2H10^w + B_3RAIN^v + B_4SUN^u >= 0$

B. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2H12^t + B_3RAIN^v + B_4SUN^u >= 0$

C. Predict Bad[y] if Index: $B_0 + B_1(\ln DA^x) + B_2(\ln H10^w) + B_3(\ln RAIN^v) + B_4(\ln SUN^u) >= 0$

D. Predict Bad[y] if Index: $B_0 + B_1(\ln DA^x) + B_2(\ln H12^t) + B_3(\ln RAIN^v) + B_4(\ln SUN^u) >= 0$

Test of Equation A n=30	No. of cases actually:	
	Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	13	1
Predicted Bad (I≥0)	4	12

Test of Equation B	No. of cases actually:	
	Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	13	1
Predicted Bad (I≥0)	4	12

Test of Equation C	No. of cases actually:	
	Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	13	1
Predicted Bad (I≥0)	4	12

Test of Equation D	No. of cases actually:	
	Not Bad (0)	Bad (1)
Not predicted Bad (I<0)	13	1
Predicted Bad (I≥0)	4	12

[z] NSI = Normalized Success Index.
[y] Bad refers to lots of fruit in which over 60% of fruit scalded.
[x] DA = harvest date as Julian day - 243.
[w] H10 = Number of preharvest hours with temperatures at or below 10°C.
[v] RAIN = Average daily mm rain from 02 or 03 September to harvest.
[u] SUN = Average daily light score from 02 or 03 September to harvest.
[t] H12 = Number of preharvest hours with temperatures at or below 12°C.

Table 4.32 Logit prediction equations to test ability to identify especially scald-resistant 'Cortland' apples. Equations: N=152, with 122 observations at 0, and 30 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	Percent of cases correctly placed	NSI[z]
A	-12	+0.096 (0.96)	+0.016 (2.11)	-0.082 (-0.49)	+11 (2.82)	-0.078 (-0.22)	82	0.353
B	-14	+0.24 (3.23)	-0.087 (-0.28)	-0.080 (-0.53)	+12 (3.16)	-0.24 (-0.71)	81	0.324
C	-40	-1.7 (-0.79)	+5.6 (3.19)	+0.19 (0.22)	+34 (3.55)	+1.1 (1.04)	86	0.457
D	-44	-5.6 (-1.78)	+8.0 (3.36)	+0.82 (0.84)	+31 (3.29)	+2.7 (2.11)	86	0.483

A. Predict Good[y] if Index: $B_0 + B_1DA^{x} + B_2H10^{w} + B_3RAIN^{v} + B_4SUN^{u} + B_5ST^{t} >= 0$

B. Predict Good[y] if Index: $B_0 + B_1DA^{x} + B_2H12^{s} + B_3RAIN^{v} + B_4SUN^{u} + B_5ST^{t} >= 0$

C. Predict Good[y] if Index: $B_0 + B_1(\ln^{r}DA^{x}) + B_2(\ln H10^{w}) + B_3(\ln RAIN^{v}) + B_4(\ln SUN^{u}) + B_5(\ln ST^{t}) >= 0$

D. Predict Good[y] if Index: $B_0 + B_1(\ln^{r}DA^{x}) + B_2(\ln H12^{s}) + B_3(\ln RAIN^{v}) + B_4(\ln SUN^{u}) + B_5(\ln ST^{t}) >= 0$

Test of Equation A n=21	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	17	1
Predicted Good (I≥0)	1	2

Test of Equation B	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	17	1
Predicted Good (I≥0)	1	2

Test of Equation C	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	17	1
Predicted Good (I≥0)	1	2

Test of Equation D	No. of cases actually:	
	Not Good(0)	Good (1)
Not predicted Good (I<0)	17	0
Predicted Good (I≥0)	1	3

[z] NSI = Normalized Success Index.
[y] Good refers to lots of fruit in which less than 20% of fruit scalded.
[x] DA = harvest date as Julian day - 243.
[w] H10 = Number of preharvest hours with temperatures at or below 10°C.
[v] RAIN = Average daily mm rain from 02 or 03 September to harvest.
[u] SUN = Average daily light score from 02 or 03 September to harvest.
[t] ST = Harvest starch score.
[s] H12 = Number of preharvest hours with temperatures at or below 12°C.

Table 4.33 Logit prediction equations to test ability to identify especially scald-resistant 'Cortland' apples. Equations: N=195, with 156 observations at 0, and 39 observations at 1.

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (T)	Percent of cases correctly placed	NSI[z]
A	-14	+0.075 (1.34)	+0.021 (3.17)	-0.049 (-0.33)	+14 (3.93)	82	0.384
B	-15	+0.21 (5.46)	+0.00016 (0.10)	-0.041 (-0.03)	+14 (4.29)	80	0.324
C	-50	-0.75 (-0.38)	+6.8 (3.96)	+0.40 (0.49)	+41 (4.65)	89	0.521
D	-56	-0.56 (-0.28)	+7.6 (4.03)	+0.84 (0.97)	+34 (4.16)	89	0.530

A. Predict Good[y] if Index: $B_0 + B_1DA^{x} + B_2H10^{w} + B_3RAIN^{v} + B_4SUN^{u} >= 0$

B. Predict Good[y] if Index: $B_0 + B_1DA^{x} + B_2H12^{t} + B_3RAIN^{v} + B_4SUN^{u} >= 0$

C. Predict Good[y] if Index: $B_0 + B_1(\ln^{s}DA^{x}) + B_2(\ln H10^{w}) + B_3(\ln RAIN^{v}) + B_4(\ln SUN^{u}) >= 0$

D. Predict Good[y] if Index: $B_0 + B_1(\ln^{s}DA^{x}) + B_2(\ln H12^{t}) + B_3(\ln RAIN^{v}) + B_4(\ln SUN^{u}) >= 0$

Test of Equation A n=30	No. of cases actually: Not Good(0)	Good (1)
Not predicted Good (I<0)	21	2
Predicted Good (I≥0)	2	5

Test of Equation B	No. of cases actually: Not Good(0)	Good (1)
Not predicted Good (I<0)	21	2
Predicted Good (I≥0)	2	5

Test of Equation C	No. of cases actually: Not Good(0)	Good (1)
Not predicted Good (I<0)	22	1
Predicted Good (I≥0)	1	6

Test of Equation D	No. of cases actually: Not Good(0)	Good (1)
Not predicted Good (I<0)	22	1
Predicted Good (I≥0)	1	6

[z] NSI = Normalized Success Index.
[y] Good refers to lots of fruit in which less than 20% of fruit scalded.
[x] DA = harvest date as Julian day - 243.
[w] H10 = Number of preharvest hours with temperatures at or below 10°C.
[v] RAIN = Aversge daily mm rain from 02 or 03 September to harvest.
[u] SUN = Average daily light score from 02 or 03 September to harvest.
[t] H12 = Number of preharvest hours with temperatures at or below 12°C.

Table 4.34 Some equations comparing ways of expressing preharvest light variation effects on scald development.

Dependent variable	Independent variables[z]	Form of independent variables	N=358 R^2	N=358 d	N=358 t for light var	N=210 R^2	N=210 d	N=210 t for light var	N=210. ST added as independent var R^2	N=210. ST added as independent var d	N=210. ST added as independent var t for light var
Scald	DA,D8	var	0.58	0.95		0.57	0.96		0.60	1.02	
Scald	DA,D8,S236	var	0.62	0.96	-6.43	0.62	1.09	-5.50	0.63	1.09	-4.05
Scald	DA,D8,S246	var	0.60	0.97	-4.17	0.62	1.04	-5.41	0.63	1.06	-4.10
Scald	DA,D8,S1WK	var	0.58	0.95	-0.29	0.59	0.96	-3.06	0.61	1.01	-2.44
$e^{(Scald/100)}$	DA,D8	var	0.58	0.95		0.57	0.98		0.61	1.06	
$e^{(Scald/100)}$	DA,D8,S236	var	0.62	0.96	-6.40	0.62	1.07	-4.95	0.63	1.09	-3.31
$e^{(Scald/100)}$	DA,D8,S246	var	0.60	0.97	-3.93	0.62	1.05	-5.24	0.64	1.09	-3.80
$e^{(Scald/100)}$	DA,D8,S1WK	var	0.58	0.95	-0.41	0.60	1.01	-3.70	0.63	1.07	-3.06
$e^{(Scald/100)}$	DA,D8	ln(var)	0.56	0.85		0.59	0.84		0.68	1.01	
$e^{(Scald/100)}$	DA,D8,S236	ln(var)	0.58	0.86	-4.23	0.64	0.96	-4.82	0.71	1.11	-3.89
$e^{(Scald/100)}$	DA,D8,S246	ln(var)	0.57	0.87	-2.31	0.65	1.02	-5.84	0.72	1.13	-5.03
$e^{(Scald/100)}$	DA,D8,S1WK	ln(var)	0.57	0.88	-2.01	0.64	0.93	-4.79	0.71	1.06	-4.33
$e^{(Scald/100)}$	DA,D6	ln(var)	0.53	0.84		0.59	1.04		0.64	1.05	
$e^{(Scald/100)}$	DA,D6,S236	ln(var)	0.62	0.98	-9.14	0.68	1.25	-7.65	0.72	1.21	-6.27
$e^{(Scald/100)}$	DA,D6,S246	ln(var)	0.55	0.90	-4.37	0.66	1.13	-6.48	0.72	1.14	-5.86
$e^{(Scald/100)}$	DA,D6,S1WK	ln(var)	0.53	0.84	-0.93	0.62	1.01	-4.08	0.69	1.02	-4.07

[z] Independent variables are as follow:
DA = Harvest date as days after 01 September.
D8(D6) = Number of days between 03 August and harvest with temperatures at or below 8(6)°C.
S236 = Average daily light score between day 236 (24 August) and harvest.
S246 = Average daily light score between day 246 (03 September) and harvest.
S1WK = Average daily light score during the week immediately preceding harvest.

Table 4.35 Some equations comparing ways of expressing preharvest rainfall variation effects on scald development.

		Form of indepen-dent variables	N=358			N=210			N=210. ST added as independent var		
Dependent variable	Independent variables[z]		R^2	d	t for light var	R^2	d	t for light var	R^2	d	t for light var
Scald	DA,D8	var	0.58	0.95		0.57	0.96		0.60	1.02	
Scald	DA,D8,R236	var	0.58	0.94	1.42	0.57	0.95	-0.72	0.60	1.01	-0.80
Scald	DA,D8,R246	var	0.58	0.95	1.26	0.58	1.00	2.30	0.61	1.05	2.64
Scald	DA,D8,R3wk	var	0.58	0.95	0.37	0.57	0.96	-0.27	0.61	1.03	1.35
$e^{(Scald/100)}$	DA,D8	var	0.58	0.95		0.57	0.98		0.61	1.06	
$e^{(Scald/100)}$	DA,D8,R236	var	0.58	0.95	1.91	0.58	0.96	-0.80	0.61	1.05	-0.89
$e^{(Scald/100)}$	DA,D8,R246	var	0.58	0.95	1.06	0.58	1.02	2.30	0.62	1.09	2.68
$e^{(Scald/100)}$	DA,D8,R3WK	var	0.58	0.95	0.11	0.57	0.98	-0.53	0.61	1.06	1.20
$e^{(Scald/100)}$	DA,D8	ln(var)	0.56	0.85		0.59	0.84		0.68	1.01	
$e^{(Scald/100)}$	DA,D8,R236	ln(var)	0.58	0.87	4.02	0.60	0.92	1.82	0.69	1.05	0.91
$e^{(Scald/100)}$	DA,D8,R246	ln(var)	0.57	0.89	2.63	0.63	1.02	4.44	0.71	1.14	4.44
$e^{(Scald/100)}$	DA,D8,R3WK	ln(var)	0.57	0.86	1.32	0.60	0.85	0.93	0.70	1.08	3.61
$e^{(Scald/100)}$	DA,D6	ln(var)	0.53	0.84		0.59	1.04		0.64	1.05	
$e^{(Scald/100)}$	DA,D6,R236	ln(var)	0.54	0.84	3.92	0.60	1.05	1.12	0.67	1.03	0.42
$e^{(Scald/100)}$	DA,D6,R246	ln(var)	0.53	0.85	-0.42	0.61	1.08	3.23	0.69	1.07	3.61
$e^{(Scald/100)}$	DA,D6,R3WK	ln(var)	0.53	0.84	0.00	0.59	1.05	0.65	0.68	1.06	3.09

[z] Independent variables are as follow:
DA = Harvest date as days after 01 September.
D8(D6) = Number of days between 03 August and harvest with temperatures at or below 8(6)°C.
R236 = Average daily rainfall in mm between day 236 (24 August) and harvest.
R246 = Average daily rainfall in mm between day 246 (03 September) and harvest.
R3WK = Average daily rainfall in mm during the three weeks immediately preceding harvest.

Table 4.36 Some equations including harvest date and a preharvest cool temperature and variable adding preharvest light and rainfall variables including their effects on scald development.

		N=358			N=210			N=210. ST added as independent var		
Dependent variable	Independent variables[z], ln transformed:	R^2	d	t for S246 (S) and R246 (R) vars	R^2	d	t for S246 (S) and R246 (R) vars	R^2	d	t for S246 (S) and R246 (R) vars
$e^{(Scald/100)}$	DA,D8	0.56	0.85		0.59	0.84		0.68	1.01	
$e^{(Scald/100)}$	DA, D8, S246	0.57	0.87	-2.31(S)	0.65	1.02	-5.84(S)	0.72	1.13	-5.03(S)
$e^{(Scald/100)}$	DA, D8, R246	0.57	0.89	2.63(R)	0.63	1.02	4.44(R)	0.71	1.14	4.44(R)
$e^{(Scald/100)}$	DA,D8,S246,R246	0.57	0.89	-1.31(S)	0.66	1.06	-4.24(S)	0.73	1.16	-3.39(S)
				1.81(R)			0.14(R)			2.50(R)
$e^{(Scald/100)}$	DA,D6	0.53	0.84		0.59	1.04		0.64	1.05	
$e^{(Scald/100)}$	DA,D6,S246	0.55	0.90	-4.37(S)	0.66	1.13	-6.48(S)	0.72	1.14	-5.86(S)
$e^{(Scald/100)}$	DA,D6,R246	0.53	0.85	-0.42(R)	0.61	1.08	3.23(R)	0.69	1.07	3.61(R)
$e^{(Scald/100)}$	DA,D6,S246,R246	0.56	0.91	-4.80(S)	0.66	1.14	-5.53(S)	0.72	1.14	-4.70(S)
				-2.01(R)			0.82(R)			1.42(R)

[z] Independent variables are as follow:
- DA = Harvest date as days after 01 September.
- D8 = Number of days between 03 August and harvest with temperatures at or below 8°C.
- S246 = Average light score between day 246 (03 September) and harvest.
- R246 = Average daily rainfall in mm between day 246 (03 September) and harvest.
- D6 = Number of days between 03 August and harvest with temperatures at or below 6°C.

CHAPTER V

RESULTS AND DISCUSSION, HRC 'DELICIOUS'

Comparison of HRC 'Cortland' and 'Delicious' Data

Because the number of samples varied according to which measurements were used, four different tables were constructed to compare the 'Cortland' and 'Delicious' data. The largest number of cases (358 for 'Cortland' and 344 for 'Delicious' (Table 5.1)) was available when starch score was not considered, and the temperature variables were given in terms of daily, rather than hourly, minima and maxima. When starch score was included and hourly temperature measurements were used for the temperature variables, the number of cases was reduced to 173 for 'Cortland' and 201 for 'Delicious'. Tables 5.2-5.5 show the means of and variations in some of the measurements, comparing 'Cortland' and 'Delicious' data. In order to demonstrate one variable's effect on another, it is necessary that there be variation in the variables. Of the measurements displayed in Tables 5.2-5.5 only harvest date measured as days after full bloom (DAFB) and average temperature from early August to harvest date (Avgtemp) had standard deviations of less than 10% of the mean.

Comparisons of 'Cortland' and 'Delicious' data within Tables 5.2-5.5 show that regardless of which data set is used, on average there was more scald on 'Cortland', and 'Delicious' were harvested later. Due to their later harvest dates, more hours and days of temperatures at or below 6, 8, 10, and 12°C had occurred before 'Delicious' harvest. More days and hours above 28 and 30°C occurred before 'Delicious' harvest than before 'Cortland' harvest. Overall, average temperature from early August to harvest was higher for 'Cortland' than for 'Delicious', but 'Cortland' were harvested with higher starch scores than were 'Delicious', which reflects slower hydrolysis of starch to sugar during ripening of 'Delicious'. On average, there was more rain during the three weeks prior to harvest of 'Cortland' fruit. The only variable which showed an inconsistent difference between 'Cortland' and 'Delicious' when different data sets were used was rainfall occurring between mid-August and harvest. Table 5.3 shows more rainfall between mid-August and harvest for 'Delicious', while Tables 5.2, 5.4, and 5.5 show no such difference.

Simple correlations between variables for 'Cortland' and 'Delicious' were also compared (Tables 5.6 to 5.8). While it is difficult to draw meaningful conclusions about differences in correlation coefficients, it may be instructive to note what appear to be large differences in correlation coefficients in view of the differences found in the measured variables. Table 5.6 focuses on the correlations of other variables with scald and starch score at harvest. Increase in starch score , during the experimental harvest periods (DA), followed a significant linear trend ($P \leq 0.01$) in both 'Cortland' and 'Delicious'. However the correlation coefficient for 'Cortland' ($r=0.86$) was much higher than that for 'Delicious' ($r=0.43$). In addition, the correlation between scald and starch, while statistically significant ($P \leq 0.01$) for both cultivars, was much higher for 'Cortland' than 'Delicious' (-0.72 vs -0.30). In Table 5.7 the focus is on the relationships of scald with numbers of preharvest hours at cool (≤ 6, 8, 10, and 12°C) and at hot (≤ 30 and 28°C) temperatures. Correlations between scald and the hours of cool preharvest temperatures were roughly equivalent for the two cultivars, but the correlation coefficients comparing preharvest high temperatures and scald, while all negative, were more negative for 'Delicious' than 'Cortland'. However, the correlation coefficients relating preharvest high temperatures (H30 and H28) to harvest date (DA) were not significant for 'Cortland', but were positive and highly significant ($P \leq 0.01$) for 'Delicious'. This suggests the possibilities 1)that there were some high temperatures late in the fall, during 'Delicious' harvest, but after 'Cortland' harvest, or 2)that the interactions among the correlated "independent" variables are responsible for this difference. This second possibility points out the difficulty of coming to really meaningful conclusions from simple correlations. Table 5.8, which shows simple correlations among other measured variables, is included to show that many interactions among variables do exist. Tables 5.6–5.8 also show that direct correlations between scald and the rainfall and light variables were not consistent. If only the data sets including starch or hourly temperature measurements were used, there was a significant ($P \leq 0.05$) negative linear relationship between scald and rainfall as measured from mid-August to harvest (RAIN236), but not as measured for the 3 weeks preceding harvest (RAIN3WK). This relationship existed for both cultivars. When all the data were included (Table 5.8), these relationships were no longer apparent. The only consistent statistically significant ($P \leq 0.05$) relationship was between scald development in 'Delicious' and the RAIN236 variable. These were all negative relationships: the more the rainfall, the less scald development. Simple correlations between scald development and preharvest light scores were negative when statistically significant ($r \leq -0.138$ is statistically significant at $P=0.05$ with 200 df). Generally, the less light and the less rainfall, the more scald developed.

One may conclude from the comparisons made in Tables 2–8 that any equations developed either to relate scald development to preharvest factors or to predict scald development based on preharvest factors will be different for 'Cortland' and 'Delicious' fruit.

<u>Building a Model to Explain Scald Variation in HRC 'Delicious'</u>

While the immediate goal was to develop a model explaining scald variation in HRC grown 'Delicious', the ultimate goal was to develop a model for explaining scald variability for fruit grown over a wide area. From many areas where data were collected, there were limited numbers of cases with all independent variables measured, so it would be well, using the HRC data, to develop models using only widely available independent variables, as well as using all variables which may be relevant.

Some Models Describing Variation in Scald Development

The data which were almost universally available were harvest date and daily temperature minima and maxima, in addition to percent of fruit developing scald after 20 weeks of storage at 0°C followed by 1 week at 20°C,. A number of variables could be created using these data. The harvest date variable, DA, was created by subtracting 143 from the number of days after 01 January that fruit were harvested. The number 143 was chosen so as to begin harvest near the number 1, but never to have a negative number for the harvest date variable. The variables relating to preharvest temperature included temperatures measured from day 215 (02 August, or, if leap year, 03 August) until the day before fruit were harvested. Table 5.9 lists the preharvest temperature variables and shows how they were generated.

The Basic Model

The simplest model using the universally available data was the following: Percent Scald = β_0 + (β_1 * DA) + (β_2 * AVGTEMP) + (β_3 * Dx), where x = 6, 8, 10, or 12. However, based on 1)the improvements in equations describing variation in scald on 'Cortland' made by transforming the scald data, and 2)the observation that scald reduction on 'Delicious', as on 'Cortland' does not begin until some time into the harvest, transforming the 'Delicious' scald data likely would be useful. One difference observed between 'Cortland' and 'Delicious' scald incidence was that no matter how late 'Cortland' fruit were harvested at the HRC, they were rarely scald-free, whereas approximately 10% of the 'Delicious' samples had no scald. In addition, because the 'Delicious' samples were at this lower limit so frequently, rather than using Ordinary Least Squares (OLS) regression, Tobit regression (which incorporates the existence of a limit to the Y variable) was used. Preliminary analyses showed that using the low temperature variable which reduced the given number of preharvest days with temperatures at or below 6, 8, 10, or 12°C by one for each preharvest day at or above 30°C (D6H, etc. in Table 5.9) was more effective for describing variation in scald development than was using the basic Dx temperature variable. Thus the equations tried were as follow: $e^{(Percent\ scald/100)} = \beta_0 + (\beta_1 * DA) + (\beta_2 * Avgtemp) + (\beta_3 * DxH)$, where x = 6, 8, 10, or 12 and a lower limit of 1 (0% scald) set for $e^{(Percent\ scald/100)}$. Table 5.10 shows these equations. Because the actual developed equations related $e^{(\%Scald/100)}$ rather than actual scald percent to the independent variables, exact interpretations of the resulting coefficients are not given. However, t-ratios of all the coefficients in the equations as constructed were statistically significant at $P \leq 0.01$ with the exceptions of those for AVGTEMP and D6H in the second equation. The first equation does not include a variable for a specific low temperature influence on scald development. It serves to show what improvement comes from adding such a variable. In the case of adding "days with temperature at or below 6°C", no improvement was seen. The greatest improvement was found when the cutoff for cool temperature effect was 12°C, followed by 8 and 10°C. In these last 3 equations the coefficients for the low temperature variables(DxH) were positive, the opposite of expected, while as average temperature(AVGTEMP) dropped and harvest(DA) occurred later, scald development was reduced, as expected. Since DA, AVGTEMP, and DxH were all correlated among one another, interpretation of the signs of the coefficients is not really possible. In any event, the last equation, which used 12°C as the temperature variable, explained 76% of the variation in $e^{(\%Scald/100)}$.

Adding a Factor for Starch Score to the Basic Model

Adding a variable for starch score to the above equations resulted in a reduction in the number of available cases from 344 to 273. Comparing Equations 1 through 5 in Table 5.11 with the corresponding equations in Table 5.10 shows slight increases in R^2 with the reduced data set in all cases except for the equation including the variable, D12H, which showed no change in R^2. When the starch variable was added to equations 1-5 in Table 5.11, corresponding equations 7-11 resulted. Equation 6 was included to see if using an equation which did not require the gathering of temperature data could give results comparable to those from equations developed using temperature data. Equation 6 described the smallest amount of variation in scald development of all the equations in Table 5.11. Inclusion of a starch factor (Equations 7-11) improved Equations 1-5 very little, if at all, and none of the t-ratios of the ST variable were statistically significant at $P \leq 0.05$. Because of the correlations among independent variables, this does not mean that scald development is unrelated to starch score; rather, it indicates that little, if any, information about scald development is added to Equations 1-5 by adding a starch factor to those equations. That Table 5.11, Equation 6, described so much less of the variation in scald development than did Table 5.11, Equations 7-11, suggests that measuring starch in fruit at harvest cannot substitute for measuring preharvest temperatures.

<u>Substituting Hourly Temperature Data for Daily Minima</u>

Substituting hourly temperature measurement data for daily minima in the HRC grown Delicious data set reduced the number of available cases from 344 to 252 if no starch score factor was included, and from 273 to 201 if starch score was included as a factor in equations describing variation in scald development.

When adding starch score as a variable in Table 5.11, above, it was necessary to redo the equations of Table 5.10 using only the data for which starch scores were available. This made it possible to directly assess the changes in the equations which resulted from the addition of starch scores. Changes due to differences in the data sets then were eliminated.

To assess whether or not using hourly temperature data increased the amount of scald variablility which could be accounted for, data from years other than 1988 and 1990-1993 could not be used. Only in these years were hourly temperature records available. Table 5.12 shows the result of remaking Table 5.10 using only those data for which hourly temperature records were available. The Tobit "R^2"s shown in Table 5.12 are somewhat higher than those in Table 5.10. With fewer years represented by the data in Table 5.12, year to year variability was reduced, thus potentially reducing error. Table 5.13 shows the result of substituting hourly temperature variables for the daily minima used in Table 5.12, while also using the same fruit samples. Clearly the hourly temperature variables did not improve the descriptions of scald variability.

Table 5.14 was constructed in a manner similar to that described for Table 5.12. It is essentially a copy of Table 5.11, but using only the data which would be available for constructing equations including starch score as well as hourly temperature data to describe scald variability. Table 5.14 confirms the demonstration in Table 5.11 that starch score does not add to the effectiveness of the equations.

In Table 5.15 hourly temperature factors were substituted for the daily temperature minima. Neither hourly temperature variables nor starch score variables created any increase in the Tobit "R^2" over using only harvest date and average preharvest temperature to describe scald variability.

Adding Factors for Rainfall and Light Variation

Rainfall was measured daily, and a light score was assigned daily throughout the years, so variables relating to these factors could be generated in many ways. For this project, two timings of influence of rainfall on scald development were considered. The first was the amount of rainfall close to the time of harvest, and the second was preharvest summer rainfall. The measurement used in the first case was average mm rainfall per day during the three weeks immediately preceding harvest(HRAIN). The measurements used for the second case were average mm rainfall per day for July(JRAIN), and separately, for August(ARAIN) preceding harvest. The light factor used was the average daily light score during the week before harvest(SUN).

Because rainfall and light data were available for all samples, no reduction in the size of the data set was required. Starch and hourly temperature factors were not used further since neither had been shown to be of value in describing variation in scald development. In addition, since using the 6°C based low temperature factor had never improved equations, its use was discontinued.

Table 5.16 shows results of adding light and rainfall factors to the equations shown in Table 5.10. These equations describe the highest percentages of variation in scald of any of the equations developed (78-84%). Use of the 12°C temperature variable resulted in the most successful equation.

Predicting Scald Development Using Logit Equations

In the previous section it was shown that the equation most effective in describing variation in scald development included factors for harvest date(DA), median daily preharvest temperature(AVGTEMP), number of preharvest days with temperature recorded at or below 12°C and corrected for days at or above 30°C(D12H), average daily light score from mid-August to harvest(SUN), and rainfall as measured during the preharvest months of July(JRAIN), August(ARAIN), and during the 3 weeks immediately preceding harvest(HRAIN). Because not all of these measurements were always available, a number of Logit equations were developed to predict scald development using combinations of the above variables as follow: DA only, (DA + AVGTEMP + D12H), (DA + AVGTEMP + D12H + JRAIN + ARAIN + HRAIN), and (DA + AVGTEMP + D12H + JRAIN + ARAIN + HRAIN + SUN).

Identifying Lots of Highly Scald Susceptible Fruit

Logit equations were developed to place lots of fruit in one of two categories, those highly susceptible to scald and those less susceptible to scald. Highly susceptible fruit were defined as those from samples (bushels) in which over 60% of fruit developed scald after 20 weeks in 0°C air followed by 1 week at room temperature (≈20°C). To test as well as develop equations, approximately 15% of the samples were selected at random for use in testing the equations developed using the remaining 85% of the samples. The top half of Table 5.17 shows the equations generated using 293 randomly selected cases, and two indicators to show how well the equations placed lots of fruit into the correct categories. The equations placed 87 to 94% of the lots of fruit correctly. The Normalized Success Indices were 0.50 to 0.72, improving as variables were added to the equation. The equations were tested using the remaining 51 cases, and results are shown on the lower half of Table 5.17. Equations A and C correctly placed all 34 of the samples which did not exceed 60% scald. Using Equation A, one would predict that when harvest is delayed until after 29 September no more than 60% of fruit would develop scald. The test of Equation A in Table 5.17 shows that this did not work for 6 of the 17 "Bad" samples. Some of the other equations were somewhat better. In practical terms, had Equation A been used to predict scald susceptibility, and fruit harvested after 29 September had received a less than full dose of scald inhibiting chemical, money would have been saved by not treating 40 of the 51 lots of fruit, but 6 of those less heavily dosed lots would have been at increased risk for scald development. Had Equation D been used, 32 lots would have received a lesser anti-scald treatment, and 2 of the 19 lots may have received more treatment than needed to control scald.

Identifying Lots of Scald Resistant Fruit

Equations comparable to those developed for Table 5.17 to identify especially scald susceptible fruit were developed to identify especially scald-resistant fruit. Scald resistant fruit were defined as those from a box in which fewer than 20% of the fruit developed scald. These are referred to as "Good" fruit. Equations are shown in Table 5.18. Comparing the NSI's of Table 5.18 with those of Table 5.17 shows that less success was met in identifying scald-resistant than scald-susceptible fruit. In general the risk may be somewhat greater for misidentifying inappropriate lots of fruit as being scald-resistant than in misidentifying categories of very scald-susceptible fruit. In the latter case, the probable assumption is that all fruit will receive some treatment, while in the former case, fruit may receive no treatment at all. There is a reasonable chance that conservative treatment would have inhibited scald to a large degree even in very scald susceptible-fruit (the up to 6 misidentified "Bad" cases in Table 5.17), but if fruit were not treated with a scald inhibitor, as might have been the recommendation for those predicted to be "good" by the equations in Table 5.18, excessive scald development might well have occurred in cases of misidentified "Not good" fruit. This would have affected from 4 lots (Equation C) to 10 lots (Equation B) out of a total of 51 lots. If chemical treatment were not available, the correct identification of 21 to 23 (depending on the equation used) "Good" lots of fruit might be worth the partial loss of the 4 to 10 misidentified "Not good" lots of fruit.

Table 5.1 Number of samples available for analysis of HRC-grown 'Delicious' and 'Cortland' apples.

Year	Delicious total	with hourly temps	with starch	with starch and hourly temps
1986	8	0	0	0
1987	60	0	60	0
1988	95	95	77	77
1989	24	0	12	0
1990	48	48	24	24
1991	45	45	45	45
1992	24	24	15	15
1993	40	40	40	40
Total	344	252	273	201

Year	Cortland total	with hourly temps	with starch	with starch and hourly temps
1985	50	0	0	0
1986	19	0	0	0
1987	15	0	15	0
1988	48	48	24	24
1989	40	0	22	0
1990	51	51	27	27
1991	60	60	60	60
1992	31	31	27	27
1993	35	35	35	35
Total	358	225	210	173

Table 5.2 Comparisons between HRC-grown 'Cortland' and 'Delicious' apples of scald development and various measured factors excluding starch scores and using low temperature days.

	Cortland						Delicious					
Variable	N	Mean	SD	SE Mean	Min	Max	N	Mean	SD	SE Mean	Min	Max
DA[z]	358	26.58	9.85	0.52	1	59	344	35.22	7.94	0.43	14	52
Scald %	358	59.30	32.30	1.71	0	100	344	35.44	35.07	1.89	0	100
DAFB[y]	358	139.63	11.56	0.61	113	167	344	145.79	9.81	0.53	120	173
D6[x]	358	5.83	4.50	0.24	0	25	344	10.01	4.53	0.24	1	20
D8[x]	358	9.22	5.31	0.28	0	36	344	14.56	5.71	0.31	2	26
D10[x]	358	14.81	7.67	0.41	0	50	344	21.88	7.47	0.40	6	33
D12[x]	358	21.68	9.13	0.48	2	63	344	30.15	9.53	0.51	10	47
D30[w]	358	7.69	4.16	0.22	0	16	344	9.40	4.63	0.25	0	16
D28[w]	358	13.16	3.89	0.21	5	19	344	14.28	4.10	0.22	6	19
AVGTEMP[v]	358	19.02	1.17	0.06	14.70	21.90	344	18.29	1.10	0.06	16.50	20.60
RAIN3WK[u]	358	4.21	2.76	0.15	0.60	10.21	344	3.88	2.99	0.16	0.61	10.21
SUN1WK[t]	358	0.46	0.19	0.01	0.07	0.86	344	0.48	0.13	0.01	0.07	0.86
RAIN236[s]	358	3.83	1.64	0.09	0.23	7.01	344	3.88	1.46	0.08	1.16	6.54
SUN236[r]	358	0.47	0.07	0.00	0.24	0.69	344	0.48	0.05	0.00	0.34	0.55

[z] DA = Harvest date as days after January 1, less 243.
[y] DAFB = Harvest date as days after full bloom.
[x] D6 = Number of preharvest days with temperatures recorded at or below 6°C. Substitute 8°C, 10°C, and 12°C for 6°C in the D8, D10, and D12 variables, respectively.
[w] D30 = Number of preharvest days with temperatures at or above 30°C. Substitute 28°C for 30°C for D28.
[v] AVGTEMP = Average of daily minimum and maximum temperatures from 02 August or 03 August to harvest.
[u] RAIN3WK = Average daily rainfall in mm for the 3 weeks immediately preceding harvest.
[t] SUN1WK = Average light score for the week immediately preceding harvest.
[s] RAIN236 = Average daily rainfall in mm from day 236 (24 or 25 August) to harvest.
[r] SUN236 = Average daily light score from day 236 to harvest.

Table 5.3 Comparisons between HRC-grown 'Cortland' and 'Delicious' apples of scald development and various measured factors including starch scores and using low temperature days.

	Cortland						Delicious					
Variable[z]	N	Mean	SD	SE Mean	Min	Max	N	Mean	SD	SE Mean	Min	Max
DA	210	27.71	10.83	0.75	1	59	273	35.97	7.91	0.48	14	52
Scald %	210	54.34	31.07	2.14	0	100	273	31.04	32.29	1.95	0	100
Starch[y]	210	3.74	1.89	0.13	1.0	7.1	273	2.74	1.22	0.07	1.0	7.0
DAFB	210	141.11	12.86	0.89	113	167	273	147.01	9.83	0.59	120	173
D6	210	6.07	5.19	0.36	0	25	273	10.33	4.46	0.27	1	20
D8	210	9.83	6.05	0.42	0	36	273	15.05	5.76	0.35	2	26
D10	210	16.29	8.26	0.57	0	50	273	22.60	7.53	0.46	6	33
D12	210	23.74	9.91	0.68	2	63	273	31.04	9.92	0.60	10	47
D30	210	8.33	3.70	0.26	3	16	273	9.96	4.23	0.26	4	16
D28	210	13.79	3.41	0.24	7	19	273	14.36	3.99	0.24	7	19
AVGTEMP	210	18.94	1.28	0.09	14.70	21.90	273	18.21	1.14	0.07	16.50	20.60
RAIN3WK	210	4.951.24	2.89	0.20	0.61	10.21	273	4.11	2.94	0.18	0.61	10.21
SUN1WK	210	0.45	0.18	0.01	0.07	0.86	273	0.48	0.13	0.01	0.07	0.86
RAIN236	210	3.77	1.62	0.11	0.23	6.46	273	4.15	1.37	0.08	1.55	6.54
SUN236	210	0.47	0.07	0.01	0.34	0.69	273	0.47	0.05	0.00	0.34	0.55

[z] Variable abbreviations which appear in Table 2 are as used in Table 2.
[y] Starch = Average starch score for fruit at harvest.

Table 5.4 Comparisons between HRC-grown 'Cortland' and 'Delicious' apples of scald development and various measured factors excluding starch scores and using low temperature hours.

	Cortland						Delicious					
Variable[z]	N	Mean	SD	SE Mean	Min	Max	N	Mean	SD	SE Mean	Min	Max
DA	225	28.47	10.54	0.70	1	59	252	34.15	8.35	0.53	14	52
Scald	225	50.97	30.27	2.02	0	100	252	35.84	36.30	2.29	0	100
DAFB	225	141.65	12.53	0.84	115	167	252	144.71	10.27	0.65	120	173
H6	225	44.96	57.46	3.83	0	396	252	59.29	43.49	2.74	0	182
H8	225	81.73	77.04	5.14	0	538	252	111.56	64.23	4.05	8	289
H10	225	139.12	104.37	6.96	0	702	252	187.67	90.54	5.70	19	407
H12	225	218.38	133.65	8.91	7	867	252	289.11	120.76	7.61	34	534
H30	225	27.44	7.93	0.53	14	40	252	30.40	8.45	0.53	14	40
H28	225	53.97	21.68	1.45	27	86	252	60.94	23.13	1.46	27	86
RAIN3WK	225	3.97	2.79	0.19	0.60	9.30	252	3.09	2.79	0.18	0.60	9.30
SUN1WK	225	0.48	0.17	0.01	0.07	0.86	252	0.48	0.13	0.01	0.07	0.86
RAIN236	225	3.39	1.50	0.10	0.23	5.90	252	3.35	1.15	0.07	1.30	5.90
SUN236	225	0.48	0.07	0.00	0.34	0.69	252	0.48	0.06	0.00	0.34	0.55

[z] Variable abbreviations are as in Table 5.3.

Table 5.5 Comparisons between HRC-grown 'Cortland' and 'Delicious' apples of scald development and various measured factors including starch scores and using low temperature hours.

	Cortland						Delicious					
Variable[z]	N	Mean	SD	SE Mean	Min	Max	N	Mean	SD	SE Mean	Min	Max
DA	173	28.92	11.04	0.84	1	59	201	34.68	8.25	0.58	14	52
Scald %	173	50.66	29.57	2.25	0	100	201	31.04	33.70	2.38	0	100
Starch	173	4.00	1.88	0.14	1.0	7.1	201	2.92	1.33	0.09	1.0	7.0
DAFB	173	143.18	12.77	0.97	115	167	201	145.73	10.35	0.73	120	173
H6	173	50.99	64.10	4.87	0	396	201	61.55	43.23	3.05	0	182
H8	173	87.23	85.68	6.51	0	538	201	114.39	63.50	4.48	8	289
H10	173	146.56	114.81	8.73	0	702	201	193.06	89.14	6.29	19	407
H12	173	224.66	145.22	11.04	7	867	201	295.89	118.60	8.37	34	534
H30	173	26.35	7.33	0.56	14	40	201	30.92	8.09	0.57	14	40
H28	173	53.47	19.28	1.47	27	86	201	63.92	20.95	1.48	27	86
RAIN3WK	173	4.58	2.88	0.22	0.60	9.30	201	3.47	2.99	0.21	0.60	9.30
SUN1WK	173	0.46	0.17	0.01	0.07	0.86	201	0.47	0.14	0.01	0.07	0.86
RAIN236	173	3.48	1.55	0.12	0.23	5.90	201	3.59	1.14	0.08	1.55	5.90
SUN236	173	0.47	0.07	0.01	0.34	0.69	201	0.48	0.06	0.00	0.34	0.55

[z] Variable abbreviations are as in Table 3.

Table 5.6 Simple correlations between starch or scald and the other variables for all HRC-grown 'Cortland' and 'Delicious' cases for which starch score was recorded.

Independent variable[z]	Cortland N=210		Delicious N=273	
DA	-0.75	0.86	-0.76	0.43
Starch	-0.72	1.00	-0.30	1.00
DAFB	-0.64	0.90	-0.67	0.56
D6	-0.64	0.76	-0.72	0.23
D8	-0.73	0.75	-0.68	0.24
D10	-0.66	0.66	-0.63	0.13
D12	-0.59	0.59	-0.49	0.07
D30	-0.37	0.18	-0.50	0.19
D28	-0.22	0.18	-0.25	0.25
AVGTEMP	0.53	-0.66	0.40	-0.10
RAIN3WK	-0.11	0.33	0.04	0.11
SUN1WK	-0.23	0.13	-0.22	-0.13
RAIN236	-0.15	0.18	-0.30	0.01
SUN236	0.05	-0.15	-0.28	0.18
	Scald	Starch	Scald	Starch

[z] Variable abbreviations are as in Table 5.3.

Table 5.7 Simple correlations between selected variables for HRC-grown 'Cortland' and 'Delicious' apples in all cases that include hourly temperature measurements.

Variable	Cortland N=225							Delicious N=252						
DA[z]	-0.70	0.72	0.81	0.86	0.88	-0.09	-0.01	-0.79	0.80	0.89	0.92	0.92	0.46	0.51
DAFB[z]	-0.52	0.60	0.63	0.65	0.62	-0.18	-0.03	-0.65	0.69	0.69	0.65	0.57	0.11	0.23
H6[y]	-0.50	1.00						-0.63	1.00					
H8[y]	-0.58	0.98	1.00					-0.70	0.97	1.00				
H10[y]	-0.64	0.95	0.99	1.00				-0.76	0.92	0.98	1.00			
H12[y]	-0.71	0.89	0.95	0.99	1.00			-0.77	0.86	0.95	0.99	1.00		
H30[x]	-0.19	-0.33	-0.22	-0.18	-0.09	1.00		-0.60	0.21	0.38	0.46	0.55	1.00	
H28[x]	-0.38	-0.14	-0.08	-0.02	0.04	0.85	1.00	-0.74	0.37	0.47	0.56	0.62	0.89	1.00
RAIN3WK[z]	-0.05	0.16	0.09	0.07	0.01	-0.11	0.22	-0.11	0.04	-0.12	-0.17	-0.26	-0.42	-0.16
SUN1WK[z]	-0.15	-0.01	0.06	0.10	0.14	0.22	0.13	-0.11	0.00	0.09	0.12	0.15	0.19	0.04
RAIN236[z]	-0.29	0.03	0.05	0.09	0.12	0.50	0.68	-0.54	0.23	0.16	0.17	0.13	0.17	0.44
SUN236[z]	-0.17	-0.20	-0.17	-0.19	-0.18	0.38	0.40	-0.35	0.19	0.32	0.36	0.43	0.66	0.60
	Scald	H6	H8	H10	H12	H30	H28	Scald	H6	H8	H10	H12	H30	H28

[z] Variable abbreviations are as in Table 5.3.
[y] H6 = Number of preharvest hours with temperatures recorded at or below 6°C. Substitute 8°C, 10°C, and 12°C for 6°C in the H8, H10, and H12 variables, respectively.
[x] H30 = Number of preharvest hours with temperatures at or above 30°C. Substitute 28°C for 30°C for H28.

Table 5.8 Simple correlations between all measured variables in all cases for HRC-grown 'Cortland' and 'Delicious' apples.

	RAIN 236[z]	SUN 1WK	RAIN 3WK	AVG TEMP	D28	D30	D12	D10	D8	D6	DAFB	Scald	DA	Delicious N=344
Cortland	-0.22	0.38	-0.51	0.38	0.70	0.76	-0.05	0.07	0.25	0.23	0.03	-0.31	0.27	SUN236
N=358		-0.04	0.75	-0.49	-0.26	-0.02	0.50	0.39	0.38	0.23	0.48	-0.29	0.34	RAIN236
DA			-0.26	-0.12	0.09	0.14	0.22	0.22	0.25	0.29	0.09	-0.15	0.20	SUN1WK
Scald %	-0.72			-0.05	-0.36	-0.39	0.11	-0.04	-0.05	-0.15	0.28	0.08	0.03	RAIN3WK
DAFB	0.87	-0.58			0.63	0.35	-0.90	-0.85	-0.74	-0.61	-0.63	0.41	-0.66	AVGTEMP
D6	0.86	-0.66	0.75			0.82	-0.44	-0.27	-0.03	0.17	0.02	-0.25	0.12	D28
D8	0.88	-0.75	0.67	0.91			-0.06	0.13	0.27	0.33	0.12	-0.53	0.33	D30
D10	0.80	-0.72	0.54	0.80	0.94			0.96	0.88	0.68	0.56	-0.51	0.78	D12
D12	0.76	-0.63	0.48	0.69	0.89	0.96			0.94	0.81	0.61	-0.67	0.86	D10
D30	0.13	-0.35	0.11	0.07	0.07	-0.01	-0.12			0.91	0.70	-0.70	0.94	D8
D28	0.21	-0.27	0.20	0.10	0.04	-0.09	-0.16	0.83			0.73	-0.74	0.91	D6
AVGTEMP	-0.71	0.46	-0.62	-0.72	-0.78	-0.82	-0.82	0.42	0.49			-0.67	0.83	DAFB
RAIN3WK	0.10	-0.05	0.28	-0.01	0.07	0.02	0.12	0.05	0.03	-0.13			-0.76	Scald %
SUN1WK	-0.02	-0.06	-0.03	0.21	0.11	0.03	-0.04	0.21	0.11	0.02	-0.22			DA
RAIN236	0.02	0.07	0.08	-0.10	-0.06	-0.14	-0.09	0.34	0.17	0.09	0.63	-0.10		
SUN236	-0.11	-0.18	-0.13	-0.10	0.02	-0.02	-0.03	0.32	0.40	0.33	-0.05	0.28	-0.36	
	DA	Scald	DAFB	D6	D8	D10	D12	D30	D28	AVG TEMP	RAIN 3WK	SUN 1WK	RAIN 236	

[z] Variable abbreviations are as in Tables 5.2 and 5.3.

Table 5.9 Temperature variables created from daily temperature minimum and maximum data. "Preharvest days" refers to the time period from August 2 or 3 to the day before fruit harvest.

Variable name	How generated
D6 (D8, D10, D12)	Number of preharvest days in which the temperature was measured at or below 6°C (8°C, 10°C, 12°C).
D30	Number of preharvest days in which the temperature was measured at or above 30°C.
D6D (D8D, D10D, D12D)	Number of preharvest days in which the temperature was measured at or below 6°C (8°C, 10°C, 12°C), with the count restarting at zero whenever the temperature reached or exceeded 30°C.
D6H (D8H, D10H, D12H)	Number of preharvest days in which the temperature was measured at or below 6°C (8°C, 10°C, 12°C), with the count reduced by one for each day (beginning August 2 or 3) the temperature reached or exceeded 30°C. D6H (D8H, D10H, D12H) defined as zero, if D6 (D8, D10, D12) - D30 < 0.
AVGTEMP	The average of the daily temperature minima and maxima from August 2 (August 3 if leap year) until the day before harvest.

Table 5.10 Tobit regression equations describing the relationships between scald development on HRC-grown 'Delicious' apples and the following factors thought to influence scald development: harvest date, average preharvest temperature, and number of preharvest days in which temperatures fell to or below 6, 8, 10, or 12°C. N=344.

		R^2 [z]
%Scald =	100 * ln(5.7 + (-0.069 * DA[y]) + (-0.097 * AVGTEMP[x]))[w]	0.64
%Scald =	100 * ln(5.0 + (-0.069 * DA) + (-0.058 * AVGTEMP) + (0.016 * D6H[v]))	0.64
%Scald =	100 * ln(-0.44 + (-0.066 * DA) + (0.21 * AVGTEMP) + (0.063 * D8H[u]))	0.70
%Scald =	100 * ln(-2.4 + (-0.065 * DA) + (0.30 * AVGTEMP) + (0.053 * D10H[t]))	0.68
%Scald =	100 * ln(-5.7 + (-.060 * DA) + (0.45 * AVGTEMP) + (0.053 * D12H[s]))	0.76

[z] R^2 is the squared correlation between observed and expected values for the Tobit regression equation $e^{(\%Scald/100)} = (\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 *$ low temperature variables as shown)) with the lower limit for $e^{(\%Scald/100)}$ defined as 1 .

[y] DA is the harvest date given as (Number of days after 01 January - 243).

[x] AVGTEMP is the average of the daily minimum and maximum temperatures from 215 days after 01 January until the day before harvest.

[w] Note that use of Tobit regression, with a lower limit of 1 for $e^{(\%Scald/100)}$ means that in cases where $(\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 *$ low temperature variables as shown)) is less than or equal to 1, Scald% is defined as 0.

[v] D6H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 6°C, reduced by 1 for each day at or above 30°C.

[u] D8H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 8°C, reduced by 1 for each day at or above 30°C.

[t] D10H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 10°C, reduced by 1 for each day at or above 30°C.

[s] D12H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 12°C, reduced by 1 for each day at or above 30°C.

Table 5.11 Tobit regression equations describing the relationships between scald development on HRC-grown 'Delicious' apples and the following factors thought to influence scald development: harvest date, average preharvest temperature, number of preharvest days in which temperatures fell to or below 6, 8, 10, or 12°C, and starch score. N=273.

Eq			R^2 [z]
1	%Scald =	100 * ln(6.0 + (-0.068 * DA[y]) + (-0.12 * AVGTEMP[x]))[w]	0.66
2	%Scald =	100 * ln(3.8 + (-0.068 * DA) + (-0.0054 * AVGTEMP) + (0.049 * D6H[v]))	0.68
3	%Scald =	100 * ln(-0.63 + (-0.064 * DA) + (0.22 * AVGTEMP) + (0.068 * D8H[v]))	0.73
4	%Scald =	100 * ln(-4.6 + (-0.065 * DA) + (0.41 * AVGTEMP) + (0.072 * D10H[v]))	0.74
5	%Scald =	100 * ln(-3.6 + (-.061 * DA) + (0.34 * AVGTEMP) + (0.045 * D12H[v]))	0.76
6	%Scald =	100 * ln(3.4 + (-0.055 * DA) + (-0.024 * ST[u]))	0.63
7	%Scald =	100 * ln(6.1 + (-0.068 * DA) + (-0.12 * AVGTEMP) + (0.0048 * ST))	0.66
8	%Scald =	100 * ln(3.9 + (-0.070 * DA) + (-0.0076 * AVGTEMP) + (0.051 * D6H) + (0.023 * ST))	0.68
9	%Scald =	100 * ln(-0.58 + (-0.067 * DA) + (0.22 * AVGTEMP) + (0.070 * D8H) + (0.028 * ST))	0.74
10	%Scald =	100 * ln(-5.2 + (-0.069 * DA) + (0.44 * AVGTEMP) + (0.078 * D10H) + (0.054 * ST))	0.75
11	%Scald =	100 * ln(-3.8 + (-0.063 * DA) + (0.35 * AVGTEMP) + (0.047 * D12H) + (0.037 * ST))	0.77

[z] R^2 is the squared correlation between observed and expected values for the Tobit regression equation $e^{(\%Scald/100)} = (\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 *$ low temperature variables as shown)) with the lower limit for $e^{(\%Scald/100)}$ defined as 1 .

[y] DA is the harvest date given as (Number of days after 01 January - 243).

[x] AVGTEMP is the average of the daily minimum and maximum temperatures from 215 days after 01 January until the day before harvest.

[w] Note that using Tobit regression, with a lower limit of 1 for $e^{(\%Scald/100)}$, in cases where $(\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 *$ low temperature variables as shown)) is 1 or less, %Scald is defined as 0.

[v] DxH is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below x°C.

[u] ST is starch score at harvest.

Table 5.12 Tobit regression equations describing the relationships between scald development on HRC-grown 'Delicious' apples and the following factors thought to influence scald development: harvest date, average preharvest temperature, and number of preharvest days in which temperatures fell to or below 6, 8, 10, or 12°C. N=252.

		R^2 [z]
%Scald =	100 * ln(6.0 + (-0.070 * DA[y]) + (-0.11 * AVGTEMP[x]))[w]	0.69
%Scald =	100 * ln(3.8 + (-0.070 * DA) + (0.027 * AVGTEMP) + (0.052 * D6H[v]))	0.70
%Scald =	100 * ln(-0.78 + (-0.069 * DA) + (0.23 * AVGTEMP) + (0.092 * D8H[u]))	0.75
%Scald =	100 * ln(-4.5 + (-0.067 * DA) + (0.41 * AVGTEMP) + (0.079 * D10H[t]))	0.75
%Scald =	100 * ln(-4.8 + (-.065 * DA) + (0.40 * AVGTEMP) + (0.066 * D12H[s]))	0.78

[z] R^2 is the squared correlation between observed and expected values for the Tobit regression equation $e^{(\%Scald/100)}$ = (β_0 + (β_1 * DA) + (β_2 * AVGTEMP) + (β_3 * low temperature variables as shown)) with the lower limit for $e^{(\%Scald/100)}$ defined as 1 .

[y] DA is the harvest date given as (Number of days after 01 January - 243).

[x] AVGTEMP is the average of the daily minimum and maximum temperatures from 215 days after 01 January until the day before harvest.

[w] Note that use of Tobit regression, with a lower limit of 1 for $e^{(\%Scald/100)}$ means that in cases where (β_0 + (β_1 * DA) + (β_2 * AVGTEMP) + (β_3 * low temperature variables as shown)) is less than or equal to 1, Scald% is defined as 0.

[v] D6H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 6°C, reduced by 1 for each day at or above 30°C.

[u] D8H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 8°C, reduced by 1 for each day at or above 30°C.

[t] D10H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 10°C, reduced by 1 for each day at or above 30°C.

[s] D12H is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 12°C, reduced by 1 for each day at or above 30°C.

Table 5.13 Tobit regression equations describing the relationships between scald development on HRC-grown 'Delicious' apples and the following factors thought to influence scald development: harvest date, average preharvest temperature, and number of preharvest hours in which temperatures fell to or below 6, 8, 10, or 12°C. N=252.

		R^2 [z]
%Scald =	100 * ln(5.9 + (-0.70 * DA[y]) + (-0.11 * AVGTEMP[x]))[w]	0.69
%Scald =	100 * ln(6.1 + (-0.070 * DA) + (-0.12 * AVGTEMP) + (-0.0087 * H6H[v]))	0.69
%Scald =	100 * ln(5.5 + (-0.076 * DA) + (-0.081 * AVGTEMP) + (0.0013 * h8H[u]))	0.69
%Scald =	100 * ln(6.2 + (-0.064 * DA) + (-0.13 * AVGTEMP) + (-0.00077 * H10H[t]))	0.69
%Scald =	100 * ln(6.0 + (-.061 * DA) + (-0.12 * AVGTEMP) + (-0.00074 * H12H[s]))	0.70

[z] R^2 is the squared correlation between observed and expected values for the Tobit regression equation $e^{(\%Scald/100)} = (\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 * \text{low temperature variables as shown}))$ with the lower limit for $e^{(\%Scald/100)}$ defined as 1 .

[y] DA is the harvest date given as (Number of days after 01 January - 243).

[x] AVGTEMP is the average of the daily minimum and maximum temperatures from 215 days after 01 January until the day before harvest.

[w] Note that use of Tobit regression, with a lower limit of 1 for $e^{(\%Scald/100)}$ means that in cases where $(\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 * \text{low temperature variables as shown}))$ is less than or equal to 1, Scald% is defined as 0.

[v] H6H is the number of hours from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 6°C, reduced by one for each hour at or above 30°C.

[u] H8H is the number of hours from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 8°C, reduced by one for each hour at or above 30°C.

[t] H10H is the number of hours from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 10°C, reduced by one for each hour at or above 30°C.

[s] H12H is the number of hours from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below 12°C, reduced by one for each hour at or above 30°C.

Table 5.14 Tobit regression equations describing the relationships between scald development on HRC-grown 'Delicious' applesand the following factors thought to influence scald development: harvest date, average preharvest temperature, number of preharvest days in which temperatures fell to or below 6, 8, 10, or 12°C, and starch score. N=201.

Eq			R^2 [z]
1	%Scald =	100 * ln(5.0 + (-0.064 * DA[y]) + (-0.071 * AVGTEMP[x]))[w]	0.69
2	%Scald =	100 * ln(2.8 + (-0.063 * DA) + (0.040 * AVGTEMP) + (0.045 * D6H[v]))	0.70
3	%Scald =	100 * ln(-1.0 + (-0.062 * DA) + (0.23 * AVGTEMP) + (0.077 * D8H[v]))	0.73
4	%Scald =	100 * ln(-3.7 + (-0.063 * DA) + (0.36 * AVGTEMP) + (0.067 * D10H[v]))	0.74
5	%Scald =	100 * ln(-4.5 + (-.062 * DA) + (0.38 * AVGTEMP) + (0.060 * D12H[v]))	0.76
6	%Scald =	100 * ln(3.5 + (-0.060 * DA) + (-0.0086 * ST[u]))	0.68
7	%Scald =	100 * ln(5.0 + (-0.065 * DA) + (-0.072 * AVGTEMP) + (0.0096 * ST))	0.69
8	%Scald =	100 * ln(2.6 + (-0.066 * DA) + (-0.049 * AVGTEMP) + (0.049 * D6H) + (0.029 * ST))	0.70
9	%Scald =	100 * ln(-1.0 + (-0.063 * DA) + (0.23 * AVGTEMP) + (0.077 * D8H) + (0.0069 * ST))	0.74
10	%Scald =	100 * ln(-4.2 + (-0.066 * DA) + (0.38 * AVGTEMP) + (0.071 * D10H) + (0.041 * ST))	0.75
11	%Scald =	100 * ln(-4.5 + (-0.062 * DA) + (0.38 * AVGTEMP) + (0.060 * D12H) + (0.0080 * ST))	0.77

[z] R^2 is the squared correlation between observed and expected values for the Tobit regression equation $e^{(\%Scald/100)} = (\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 * \text{low temperature variables as shown}))$ with the lower limit for $e^{(\%Scald/100)}$ defined as 1 .

[y] DA is the harvest date given as (Number of days after 01 January - 243).

[x] AVGTEMP is the average of the daily minimum and maximum temperatures from 215 days after 01 January until the day before harvest.

[w] Note that using Tobit regression, with a lower limit of 1 for $e^{(\%Scald/100)}$, in cases where $(\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 * \text{low temperature variables as shown}))$ is 1 or less, %Scald is defined as 0.

[v] DxH is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below x°C.

[u] ST is starch score at harvest.

Table 5.15 Tobit regression equations describing the relationships between scald development on HRC-grown 'Delicious' apples and the following factors thought to influence scald development: harvest date, average preharvest temperature, number of preharvest days in which temperatures fell to or below 6, 8, 10, or 12°C, and starch score. N=201.

Eq			R^2 [z]
1	%Scald =	100 * ln(4.9 + (-0.064 * DA[y]) + (-0.068 * AVGTEMP[x]))[w]	0.69
2	%Scald =	100 * ln(4.8 + (-0.064 * DA) + (-0.062 * AVGTEMP) + (0.00024 * H6H[v]))	0.69
3	%Scald =	100 * ln(4.3 + (-0.073 * DA) + (-0.025 * AVGTEMP) + (0.0020 * H8H[v]))	0.69
4	%Scald =	100 * ln(4.7 + (-0.068 * DA) + (-0.057 * AVGTEMP) + (0.00052 * H10H[v]))	0.69
5	%Scald =	100 * ln(4.9 + (-0.066 * DA) + (-0.066 * AVGTEMP) + (0.00019 * H12H[v]))	0.69
6	%Scald =	100 * ln(3.5 + (-0.060 * DA) + (0.0086 * ST[u]))	0.68
7	%Scald =	100 * ln(4.9 + (-0.065 * DA) + (-0.068 * AVGTEMP) + (0.0094 * ST))	0.69
8	%Scald =	100 * ln(4.9 + (-0.065 * DA)+(-0.063 * AVGTEMP)+(0.00020 * H6H)+(0.0090 * ST))	0.69
9	%Scald =	100 * ln(4.28 + (-0.075 * DA)+(-0.024 * AVGTEMP)+(0.0021 * H8H)+(0.015 * ST))	0.69
10	%Scald =	100 * ln(4.7 + (-0.071 * DA)+(-0.054 * AVGTEMP)+(0.00070 * H10H)+(0.016 * ST))	0.69
11	%Scald =	100 * ln(4.9 + (-0.070 * DA)+(-0.065 * AVGTEMP)+(0.00036 * H12H)+(0.016 * ST))	0.69

[z] R^2 is the squared correlation between observed and expected values for the Tobit regression equation $e^{(\%Scald/100)} = (\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 * \text{low temperature variables as shown}))$ with the lower limit for $e^{(\%Scald/100)}$ defined as 1 .

[y] DA is the harvest date given as (Number of days after 01 January - 243).

[x] AVGTEMP is the average of the daily minimum and maximum temperatures from 215 days after 01 January until the day before harvest.

[w] Note that using Tobit regression, with a lower limit of 1 for $e^{(\%Scald/100)}$, in cases where $(\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 * \text{low temperature variables as shown}))$ is 1 or less, %Scald is defined as 0.

[v] DxH is the number of hours from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below x°C, less one for each hour at or above 30°C.

[u] ST is starch score at harvest.

Table 5.16 Tobit regression equations describing the relationships between scald development on HRC-grown 'Delicious' apples and the following factors thought to influence scald development: harvest date, average preharvest temperature, number of preharvest temperatures at or below 8, 10, or 12°C, average daily light score from mid-August to harvest, and several rainfall factors. N=344, with 38 limit observations, 306 non-limit observations.

		R^2 [z]
%Scald =	100 * ln(2.9 + (-0.063 * DA[y]) + (0.058 * AVGTEMP[x]) + (0.044 * D8H[w]) + (-2.3 * SUN[v]) + (0.044 * JRAIN[u]) + (0.11 * ARAIN[t]) + (-0.026 * HRAIN[s]))[r]	0.78
%Scald =	100 * ln(-3.5 + (-0.054 * DA) + (0.36 * AVGTEMP) + (0.061 * D10H[w]) + (-2.1 * SUN) + (0.022 * JRAIN) + (0.12 * ARAIN) + (-0.0090 * HRAIN))	0.80
%Scald =	100 * ln(-4.5 + (-0.046 * DA) + (0.42 * AVGTEMP) + (0.049 * D12H[w]) + (-3.6 * SUN) + (0.035 * JRAIN) + (0.11 * ARAIN) + (-0.025 * HRAIN))	0.84

[z] R^2 is the squared correlation between observed and expected values for the Tobit regression equation $e^{(\%Scald/100)} = (\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 *$ low temperature variables as shown)) with the lower limit for $e^{(\%Scald/100)}$ defined as 1 .

[y] DA is the harvest date given as (Number of days after 01 January - 243).

[x] AVGTEMP is the average of the daily minimum and maximum temperatures from 215 days after 01 January until the day before harvest.

[w] DxH is the number of days from 215 days after 01 January until the day before harvest in which the temperature was recorded at or below x°C, reduced by 1 for each day at or above 30°C.

[v] SUN is the average daily light score from mid-August to harvest.

[u] JRAIN is the average daily rainfall in mm during July.

[t] ARAIN is the average daily rainfall in mm during August.

[s] HRAIN is the average daily mm rain during the three weeks before harvest.

[r] Note that use of Tobit regression, with a lower limit of 1 for $e^{(\%Scald/100)}$ means that in cases where $(\beta_0 + (\beta_1 * DA) + (\beta_2 * AVGTEMP) + (\beta_3 *$ low temperature variables as shown)) is less than or equal to 1, %Scald is defined as 0.

Table 5.17 Logit prediction equations to test ability to identify especially scald susceptible 'Delicious' apples. Equations: n=293, with 209 observations at 0, and 84 observations at 1.

	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	B_6 (t)	B_7 (t)	% of cases correctly placed	NSI[z]
A	8.9	-0.30 (-8.59)							88	0.500
B	-93	-0.33 (-6.72)	5.0 (5.14)	0.51 (5.48)					87	0.633
C	-103	-0.32 (-4.64)	5.5 (4.05)	0.53 (4.93)	-0.26 (-1.25)	0.26 (1.39)	-0.065 (-0.78)		94	0.704
D	-107	-0.28 (-3.70)	6.1 (4.09)	0.55 (4.54)	-0.041 (-0.18)	0.45 (2.17)	-0.15 (-1.61)	-24 (-3.03)	91	0.721

A. Predict Bad[y] if Index: $B_0 + B_1DA^x \geq 0$

B. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2AVGTEMP^w + B_3D12H^v \geq 0$

C. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2AVGTEMP^w + B_3D12H^v + B_4JRAIN^u + B_5ARAIN^t + B_6HRAIN^s \geq 0$

D. Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2AVGTEMP^w + B_3D12H^v + B_4JRAIN^u + B_5ARAIN^t + B_6HRAIN^s + B_7SUN^r \geq 0$

Test of Equation A n=51	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted bad (I<0)	34	6
Predicted bad (I≥0)	0	11

Test of Equation B	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted bad (I<0)	32	4
Predicted bad (I≥0)	2	13

Test of Equation C	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted bad (I<0)	34	1
Predicted bad (I≥0)	0	16

Test of Equation D	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted bad (I<0)	32	0
Predicted bad (I≥0)	2	17

[z]NSI = Normalized Success Index.
[y]Bad refers to lots of fruit in which over 60% of fruit scalded.
[x]DA = harvest date as Julian day - 243.
[w]AVGTEMP = Average of median daily preharvest temperatures.
[v]D12H = Number of preharvest days with temperatures at or below 12°C, less one for each day at or above 30°C.
[u]JRAIN = Average daily mm rain during July.
[t]ARAIN = Average daily mm rain during August.
[s]HRAIN = Average daily mm rain during the 3 weeks preceding harvest.
[r]SUN = Average light score from mid-August to harvest.

Table 5.18 Logit prediction equations to test ability to identify especially scald resistant 'Delicious' apples. Equations: n=293, with 151 observations at 0, and 142 observations at 1.

	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	B_6 (t)	B_7 (t)	% of cases correctly placed	NSI[z]
A	-7.8	0.22 (8.19)							78	0.330
B	43	0.29 (7.04)	-2.6 (-4.25)	-0.32 (-5.15)					76	0.431
C	66	0.21 (3.79)	-3.7 (-3.53)	-0.34 (-4.12)	0.39 (1.92)	-0.20 (-1.19)	-0.043 (-.37)		82	0.532
D	101	0.091 (1.19)	-5.7 (-3.89)	-0.49 (-4.01)	0.18 (0.63)	-0.56 (-2.35)	0.038 (0.21)	25 (3.1)	83	0.558

A. Predict Good[y] if Index: $B_0 + B_1DA^x \geq 0$

B. Predict Good[y] if Index: $B_0 + B_1DA^x + B_2AVGTEMP^w + B_3D12H^v \geq 0$

C. Predict Good[y] if Index: $B_0 + B_1DA^x + B_2AVGTEMP^w + B_3D12H^v + B_4JRAIN^u + B_5ARAIN^t + B_6HRAIN^s \geq 0$

D. Predict Good[y] if Index: $B_0 + B_1DA^x + B_2AVGTEMP^w + B_3D12H^v + B_4JRAIN^u + B_5ARAIN^t + B_6HRAIN^s + B_7SUN^r \geq 0$

Test of Equation A n=51	No. of cases actually: Not good (0)	Good (1)	Test of Equation B	No. of cases actually: Not good (0)	Good (1)
Not predicted good (I<0)	21	4	Not predicted good (I<0)	16	2
Predicted good (I≥0)	5	21	Predicted good (I≥0)	10	23

Test of Equation C	No. of cases actually: Not good (0)	Good (1)	Test of Equation D	No. of cases actually: Not good (0)	Good (1)
Not predicted good (I<0)	22	4	Not predicted good (I<0)	20	2
Predicted good (I≥0)	4	21	Predicted good (I≥0)	6	23

[z]NSI = Normalized Success Index.
[y]Good refers to lots of fruit in which fewer than 20% of fruit scalded.
[x]DA = harvest date as Julian day - 243.
[w]AVGTEMP = Average of median daily preharvest temperatures.
[v]D12H = Number of preharvest days with temperatures at or below 12°C, less one for each day at or above 30°C.
[u]JRAIN = Average daily mm rain during July.
[t]ARAIN = Average daily mm rain during August.
[s]HRAIN = Average daily mm rain during the 3 weeks preceding harvest.
[r]SUN = Average light score from mid-August to harvest.

CHAPTER VI

RESULTS AND DISCUSSION, WORLDWIDE 'DELICIOUS'

Comparisons of 'Delicious' Data From Different Areas

Poststorage scald data and preharvest climate and maturity data were taken from a number of areas worldwide over a number of years. In order to assess effects of climate and maturity of fruit at harvest on scald, it may be beneficial to compare the values of these factors. Table 6.1 shows where samples were taken. The largest blocks of samples are from Massachusetts, USA, Elgin, South Africa, and British Columbia, Canada. The Massachusetts samples are the ones that were analyzed in Chapter V. The samples from British Columbia are from 15 orchards, and temperature records were kept separately for each orchard. All fruit were stored together, however. Because light data were only available from Massachusetts, USA and Elgin, SA and measurements were taken in different ways in the two areas, effects of light on scald incidence are not discussed in this chapter, but are taken up later.

Table 6.2 shows how much scald developed on fruit grown in the areas shown. Since no scald ever developed on fruit grown in Otago, NZ, these data can only be used if Otago can be grouped with another area for describing effects of preharvest factors on scald development. Except for Otago, all areas produced fruit with enough scald, and enough variation in scald, so that if the measured factors affect scald development, it may be possible to quantify such effects. Because the seasons in the northern and southern hemispheres are reversed, harvest date must be expressed in a way which reflects similar stages of fruit development. Comparing the harvest dates in the northern and southern hemispheres showed harvests shifted nearly seven months (mean harvest date in northern hemisphere = 27 September; mean harvest date in southern hemisphere = 5 March) so it was decided to shift the harvest date ahead seven months for the southern hemisphere fruit samples. When actual dates for the southern hemisphere are stated, however, they are the real dates.

The first rows of Table 6.3 show the average daily mean temperature from day 215 (1 January in the southern hemisphere, 3 or 4 August in the northern hemisphere) to the day before fruit harvests. Average daily mean temperatures were highest in West Virginia and lowest in Canterbury and Otago districts of New Zealand. Average temperatures do not tell the whole story, however. In some areas daily temperature extremes are greater than in others. Table 6.3 shows average numbers of preharvest days with temperatures at or below 6, 8, 10, and 12°C, while Table 6.4 shows average numbers of preharvest days with temperatures at or above 30, 28, and 25°C. Means are averages of information relating to individual harvested fruit samples, so time of harvest is a factor in these tables. If fruit were harvested unusually early, fewer days with cool temperatures will have accumulated. Because it is not known in some cases if samples were picked prior to or later than normal commercial harvest dates, it is unclear if differences in data shown in Table 6.3 relate to real differences in preharvest temperature prior to normal harvest or if the data have been affected by inclusion of fruit harvested deliberately long before and/or after normal commercial harvest periods. In any case these temperature data reflect conditions under which the fruit sampled in this study were grown.

A number of observations can be made regarding varying temperature extremes in the fruit-growing areas in Tables 6.3 and 6.4. While West Virginia clearly had the highest average preharvest temperatures of any of the areas samples, it did not have the fewest days with the very coolest temperatures (D6). Both South African locations and two of the New Zealand locations averaged fewer days at or below 6°C (Table 6.3). West Virginia did, however, have more hot days (days with temperatures at or above 25, 28, or 30°C) than any of the other areas. Lowest preharvest average temperatures were in

Canterbury, which also had among the fewest days with high temperatures.

Clearly, the daily temperature patterns are different in different areas. Length of harvest period can both influence and be influenced by preharvest temperature patterns. High temperatures can promote ripening; low temperatures may retard ripening. If fruit are harvested over a long period, there is then a long period of time in which temperatures may fluctuate or in which an autumn cooling trend may show itself. What actually happens varies by location. Combining data from Tables 6.2 and 6.3, one finds that the shortest harvest period (26 days) was in British Columbia, which also had the greatest variation in preharvest temperature means, and where the very lowest temperature means (12.9°C) were recorded. The longest harvest period (72 days) was in Hawkes Bay, NZ where some of the highest temperature means were recorded, and mean temperature did not vary much through the harvest period. Thus, universal relationships between temperature mean and length of harvest period cannot be established.

Rainfall measurements are shown in Table 6.5. Of the areas for which rainfall data were available, Massachusetts was the wettest at all the time periods measured. The High Noon, S.A. location was the driest.

It is not clear what effect these gross climatic differences may have on scald development, but it may be well to keep the differences in mind for reference if some of these factors seem to have different effects on scald of fruit grown in different areas.

Harvest starch scores are given in Table 6.6. Average scores ranged from 1.6 in Washington to 3.1 in Canterbury, NZ. Comparisons of starch scores from different locations may not be valid, as not everyone reads the starch charts from which the scores are derived the same way. This is an inherent weakness in any system that uses this subjectively determined variable. Most people are able to read the charts consistently, and groups of people who work at it together can be consistent within the group, but group-to-group differences in interpretation may occur. However, the difference between a mean harvest starch score of 1.6 and a mean harvest starch score of 3.1 is large enough that it is likely to be real, in spite of possible differences in readings of starch charts. For purposes of this study it is necessary to assume consistent readings of starch charts.

<u>Simple Models Including All 'Delicious' Cases</u>

A total of 1186 samples of lots of 'Delicious' fruit were available. For each of these samples, poststorage scald development and date of harvest were available. None of the other measured factors was available for all 1186 cases. A series of equations using only harvest date as the factor influencing scald development is shown in Table 6.7. The set of four equations shows how well variation in scald development is described using only harvest date as an influencing factor, and varying the constraints on possible differences in coefficients based on location of orchards. Ten different fruit growing regions are shown. Equation A relates scald development to harvest date assuming the relationship is the same regardless of global fruit-growing location. (It is also assumed that fruit are harvested seven months earlier in the southern hemisphere than in the northern hemisphere). This Equation A, in which it is assumed that both constant and DA coefficient are the same for all locations, describes 22% of the variation in scald development. When the constraint that the constants must be the same for all locations is lifted (Equation B), the R^2 increases to 0.32. Using Chow's test to compare these first two equations, the F is significant (P=0.01) indicating that the constant is not the same for all locations. Shifting the harvest date by seven months in the southern hemisphere (rather than the logical six months) from that in the northern hemisphere was done somewhat arbitrarily. However, Chow's test allows the constants for southern hemisphere locations to be tested,determining whether or not this shift should be rejected.

Because there were no clear differences between constants for the northern vs southern hemispheres, the seven-month shift was not rejected. Chow's test does show that significant differences among the constants do exist (Equation A vs Equation B). Equation C, which allows the DA coefficient to vary resulted in an equation R^2 of 0.29. This equation also was significantly different (P = 0.01) from Equation A when Chow's test was applied. The last equation, Equation D, in which both the constant and the DA coefficient were allowed to vary by location, described 49% of the variation in scald development. Equation D was shown to be different (P = 0.01) from each of the other three equations when Chow's test was applied. Nearly half of the variation in scald of fruit grown in a defined area may be explained by differences in harvest date, if constant and slope of harvest date effect are allowed to vary by fruit-growing location. Various transformations of the variables had proven useful in describing scald variation in the 'Cortland' data. When exponential transformation of percent scald and logarithmic transformation of harvest dates were done, no improvement in abilities of equations to explain scald variation was found (Table 6.8). Areas referred to in Table 6.8 are the same as those shown in Table 6.7, and constraints on coefficients match those in Table 6.7 according to Equations A to D.

While separating effects on scald development by year is not useful if one is attempting to predict future scald development, it may be instructive in evaluating a given factor's overall effect on scald, as well as providing information which may lead to determining what other factors which differ from year to year might be responsible for differences in scald development. Table 6.9 shows results of separating cases by location, as was shown necessary in Table 6.7, and also making a separate equation for each year within each location. If Equations B and C do not differ from Equation A, then the effects of the included independent variables may be considered to be the same in all years. Except for Hawkes Bay and Nelson, NZ, Equation B was different from Equation A. Equation B can differ from equation A for a number of reasons. Firstly, some factor which may or may not be related to included factors and which varies from year to year may be influencing scald development, which is likely. Secondly, the effects of the included factors themselves may vary from year to year, being influenced by another factor. If Equation C differs from Equation A or B, then any of the above situations may exist. If Equation C does not differ from Equation B, then the DA coefficient is not different for the different years. This is shown to be the case for British Columbia, Hawkes Bay, Nelson, High Noon, and West Virginia. When four years of data on harvest date and subsequent poststorage scald development on fruit grown at the Elgin, SA location were consolidated, the resulting OLS equation (A) explained essentially none of the variation in scald development. If it was assumed that some unknown factor which varied from year to year was influencing scald development, but still the rate of scald reduction based on advancing harvest date was the same in all years (Equation B), the R^2 increased from 0.00 to 0.61, a substantial increase. Further, if the rate of change related to harvest date was also allowed to vary from year to year (Equation C), the R^2 increased to 0.83, again a significant increase. Thus it may be concluded that in individual years scald development does decrease in a significant linear fashion with advancing harvest date (B_1 is positive) in fruit grown at Elgin (and everywhere else investigated in Table 6.9), but in all likelihood the factor(s) causing changes in scald development also relate(s) to something else which also changes over time. If the "something" were consistent from year to year, then predictions could be made using harvest date, but Table 6.9 shows that only in the Nelson based equations were B_0 and B_1 not different in different years.

Adding More Variables to the Equations

Clearly, harvest date alone cannot explain all, or, in many locations, even most of the differences in scald development. Because the data base is reduced whenever more variables are added to equations, and a large data base is desired, and different information is missing from different areas and years, a number of combinations of variables were used to develop additional models.

Average Preharvest Temperature

Table 6.10 shows the effect of adding average preharvest temperature as a variable to the basic equations of Table 6.9. Because average temperatures were not available for Washington, that area had to be eliminated from the model. Also, two years were eliminated from the Massachusetts data; in 1987 there were only two different percentages of scald were observed, and in 1989 there were only two harvest dates, thus equations with a constant and two other coefficients could not be fit to data from these years. All equations, except those from Massachusetts, contain the same cases in Table 6.9 as in Table 6.10. Chow's test therefore can be applied to comparable equations in Table 6.9 vs Table 6.10 (except for Massachusetts) to test whether or not the assumption made in Table 6.9 that the coefficient for AVGTEMP is zero should be rejected. Results are not shown, but the only locations for which the assumption that AVGTEMP's coefficient is zero could not be rejected were Elgin (Equations A and C) and High Noon (Equation C). Only in the Nelson equations did the B's not vary significantly from year to year.

Starch

Table 6.11 is similar to Table 6.10, but harvest starch score is examined, rather than average preharvest temperature effect on scald. Only the British Columbia and Washington equations were generated from the same cases in Tables 6.9 and 6.11, so only those two sets of equations could be compared using Chow's test, and only the "A" equations using the British Columbia data failed to reject the hypothesis that the ST coefficient was zero (Chow's F tests not shown). Again only the Nelson equations' B values were not significantly different from year to year.

Table 6.12 puts together both the preharvest temperature and starch effects. Equations A, B, and C in Table 6.12 are basically repeated from Tables 6.9, 6.10, and 6.11 using only the cases for which both average preharvest temperature and harvest starch score, as well as harvest date and poststorage scald development were available in sufficient quantities to develop equations. Equation D incorporates all three variables (DA, ST, and AVG). Equations A through D have the constraint that all coefficients are the same in all years. Equation E is similar to Equation D except that the constant is allowed to vary by year. Thus Equation E could not be used for prediction, but could be used to indicate how rapidly scald development might be reduced as DA, ST and AVG changed through the harvest season. Equation F, in which all coefficients vary from year to year is purely descriptive, and could not be used in prediction. The last column in Table 6.12, which incorporates all of the available data, shows a significant (P=0.01) relationship (which is not shown, but is negative) between scald and harvest date, but the R^2 of the equation was only 0.17, not high enough to be of use for predicting scald. Addition of factors for AVG and ST did not improve the equation significantly. However, if the individual areas were allowed different B_0's (second to last column, Table 6.12), Equations A through D were all significantly improved (Chow's F's not shown). Equation D explained 32% of the overall variation in scald, without taking year-to-year differences into account. If B_0 varied by year within area, as well as within area (Equation E), R^2 increased to 0.65. DA, AVG, and ST were still statistically significant as in Equation D above (not shown). Chow's F, comparing Equations D and E, was significant at P=0.01, but of course Equation E could not be used for prediction at all. Looking at the equations for the individual areas, some differences in the effects of DA, AVG and ST on scald development existed. Using Chow's test to compare Equation D, Table 6.12 (which could be used to predict future scald) to Equation F, Table 6.12

(which is comprised of the equations from individual years and, therefore could not be used for prediction) gives significant F values (P=0.01) for all areas except Nelson. Chow's F for the Nelson equations was 0.68, (4,11 df) which was not statistically significant, but it included only two years of data. At the opposite extreme lay Elgin, whose data from 4 years, when separate coefficients were allowed for each effect in each year, resulted in an equation with R^2 of 0.89, but when one coefficient per variable was allowed for all years, an equation with R^2 of only 0.29 was generated. Chow's F, comparing these two equations, was 107.71 (12/234 df), significant at P=0.001. Some factor not taken into account which either varied much less in Nelson than in Elgin, or was less well correlated to factors included in the equations for Elgin than for Nelson, must have caused these varying year-to-year differences. As long as year-to-year differences are not taken intp account, some important factor affecting scald development is not being considered, and predictions will not be entirely satisfactory.

Specific Cool Temperatures

Results of addition of a specific temperature below which scald susceptibility may be reduced are shown in Table 6.13. Equations are comparable to the "D" equations in Table 6.12. Theoretically, except for the "all areas" equations, they could be used for prediction. The top group of equations shows that, overall, adding a factor for number of preharvest days with temperatures at or below 6°C increased the R^2 of the original equation more than adding such a factor for 8, 10, or 12°C. Applying Chow's test to compare each of the equations incorporating a specific low temperature factor to the top equation showed that the D6 and D8 factors changed the equation significantly (P=0.01), while the D10 and D12 factors did not (P=0.05)(data not shown). If one looks at the individual coefficients making up these five equations, one sees that when a D6 factor was in the equation, AVG was not statistically significant (P=0.05), but when either no low temperature variable, the D8 variable, or the nonsignificant D10 or D12 variable was in an equation, the AVG effect was significant and positive (P=0.05). If AVG is left out of the D6 or D8 equation, Chow's test shows that the equation is not different than if AVG were there (not shown). AVG is correlated with D6, D8, D10, and D12, all of which also are intercorrelated. It appears, therefore, that the AVG effect is not separate from the D6 and D8 effects.

Looking at the separate equations made for each area (Table 6.13), a number of observations can be made. Firstly, where the Dx effects are statistically significant, the sign is usually positive, although it is well established that poststorage scald decreases with increasing preharvest cool temperature. (In the "all areas" equations the Dx signs are, as expected, negative when significant). Secondly, there is not one temperature cutoff which is consistently more effective in changing an equation than another. Thirdly, not only are the Dx signs not as expected, but for the Canterbury and Elgin equations, the DA signs are not as expected either, and for the Massachusetts equations the ST and AVG signs are not as expected. A simple explanation for these unexpected effects may be found in the correlations among the independent variables. Table 6.14 shows the simple correlation coefficients relating the independent variables used in Table 6.13. (The relationships involving D6, D8, and D10 are similar to those involving D12.) All the r's in Table 6.14 are significant at P=0.01, except for the r relating ST to AVG, which is not significant at P=0.05. These correlations are not surprising considering that as the harvest season progresses DA increases, ST increases, AVG decreases, and the Dx's increase. The result is that effects of the variables in the equations will likely confound one another, and it is not surprising that the equations fail to give coefficients of the expected sign. When smaller data sets are used these correlations become larger. Note that when the large data set is used, in the "all areas" equations in Table 6.13, the signs of the coefficients are as expected. Table 6.14 also shows correlations among the independent variables using only six years of the HRC data, and using only one year, 1993, of the HRC data. While the equations in Table 6.13 show negative coefficients for AVG and positive coefficients for ST and D12 in Massachusetts (HRC), the correlation table in Table 6.14 for HRC-grown fruit shows AVG positively correlated with scald and ST, and D12 negatively correlated with scald, as expected. When only the 1993 HRC data were used (Table 6.16), the correlation coefficients among the variables were so high that there can be no way to separate effects at all. (This is why a huge and varied data set is so necessary for separating effects.) Table 6.15 shows equations generated from the 1993 HRC 'Delicious' data. The top equation, which includes five variables shown in Table 6.14 (the high temperature variable D25W will be discussed further), has an R^2 of 0.91, yet none of the independent variables contributes in a statistically significant way to the equation. If only one (any one) of the independent variables is used (last 5 equations Table 6.15), its contribution is statistically significant. When combinations of independent variables were used, most were found nonsignificant, and the more variables that were in the equation, the more likely that a variable was to be found nonsignificant.

The finding that the highest R^2 occurs when using the most uniform group of data cannot be surprising. What is of interest is that using the most diverse data set, the top equations in Table 6.13, resulted in equations whose independent variables had the expected signs. Even in these equations, AVG and the Dx's were so strongly correlated that when both AVG and a Dx were in an equation, only one was statistically significant. Using the same coefficients (except for the constant) for all areas resulted in an equation that described as much as 37% of the variation in scald development. While this may not be adequate for predicting scald, it does confirm the effects of harvest date, harvest starch score, and preharvest temperature on poststorage scald develpment in 'Delicious'.

<u>High Temperatures</u>

Preharvest high temperatures have been associated with an increase in poststorage scald development. It is difficult to quantify preharvest high temperature in a way that might be useful as a variable in an OLS equation describing scald variation because while it is postulated that more high temperatures will lead to greater scald development, the number of days at or above any given temperature can only increase as time passes. Therefore, to avoid having the high temperature variables necessarily increase with time, the variables generated were number of days at or above 30, 28, or 25°C during the week before harvest (D30W, D28W, and D25W).These coefficients, shown in Table 6.14 do not, overall, have a direct relationship with scald development. However, in 1993, in Massachusetts, the D25W variable did have a significant positive sign in a number of the equations shown in Table 6.15. Table 6.16 gives information regarding preharvest high temperatures in areas where this information was available. Very few cases were available which were subjected to temperatures over 30°C. Table 6.17 shows results of adding preharvest high temperature variables to equations already containing variables for harvest date and starch score, and for preharvest average and low temperatures. In no case where Chow's test could be performed did the addition of one of these high temperature variables significantly change an equation. However, when the most complete data set was used, the D30W and D25W coefficients were positive and statistically significant, consistent with the hypothesis that preharvest high temperature increases scald development.

<u>Rainfall</u>

The other two factors which were measured, rainfall and light, are not necessarily as intercorrelated with the other independent variables as the others are with each other. Since light measurements were only made in two locations, and those measurements were taken in different ways, it is not possible to assess overall light effects.

Rainfall measurements, however, are available for all of the 772 cases most recently discussed except for the 213 cases from British Columbia. Table 6.18 shows means of preharvest rainfall and correlations between preharvest rainfall and poststorage scald and some of the other independent variables used in describing scald variation. Note the very high correlation coefficients for Canterbury, with only one year's data. In the case of SCALD vs the rainfall variables, the only simple correlation, other than the ones for Canterbury, which is statistically significant at P=0.05 is Massachusetts' R236 vs SCALD. Of the correlations between the other variables and the rainfall variables shown in Table 6.18, some are statistically significant at p=0.05, but aside from the one-year Canterbury correlations, none are so high as to be almost completely defined by another variable. Table 6.19 does for the rainfall variables what Table 6.13 did for the "Number of preharvest days at or below" variables. In the case of the rainfall variables, there was a consistent best choice, R236. In all groups Chow's test showed that the equation including R236 was different from the equation without a rainfall variable (Chow's F tests not shown). In all groups except Massachusetts the R236 equation had the lowest Error Sum of Squares, and in the Massachusetts data, there were differences among the equations which used a rainfall variable. Effects of varying rainfall on scald development were sometimes positive and sometimes negative. These differences were not based on absolute amounts of rainfall. The highest mean rainfall, by any of the measures used, was in Massachusetts where rainfall was negatively correlated to scald, and the coefficients in the equations in Table 6.19 also were negative. The lowest mean rainfall was recorded at Elgin, SA where scald was not correlated to rainfall, but rainfall coefficients were mixed in Table 6.19. Data from Hawkes Bay, NZ, with intermediate rainfall levels, gave positive coefficients for rainfall in the equations in 6.19. Overall, the rainfall measure, R236, had a negative coefficient in combined area equation in Table 6.19.

Light

Since light data were available only for Massachusetts, USA and Elgin, SA, and those measurements were recorded differently, no universal light effects can be determined. Table 6.20 shows equations including a light factor to describe variation in poststorage scald development in those two areas. When the two sets of data were combined each area was allowed its own coefficient for light since the measurements were different. Chow's test (F not shown) showed that the equations combining data from both areas were significantly different at P=0.01 from equations made separately for each area. In all cases except for the combined equation using S1WK as the light variable for Elgin, and the MA equation using S236, the coefficient for light score was negative. Thus, it appears that having relatively less preharvest light was associated with greater amounts of poststorage scald. Table 6.21 shows simple correlation coefficients between light score and other variables associated with scald development. Note that Scald vs either S236 or S1WK had a positive significant (P=0.01) r for Elgin, but that the coefficients for S236 and S1WK were negative for Elgin in the equations in Table 6.20. Correlations among variables used in the equations may account for this seeming contradiction.

Hourly Temperatures

It was shown in Chapter V that using hourly, rather than daily, temperature information did not add to the explanation of variation in scald development in Massachusetts-grown 'Delicious'. To see if hourly information might be of more value when applied to data from other locations a number of equations were generated. Table 6.22 shows equations equivalent to those in Table 6.13, but substituting number of preharvest hours for number of preharvest days at or below

6, 8, 10, and 12°C. The British Columbia, Nelson, Canterbury, and Elgin equations used the same cases for both sets of equations. Because of differences in rounding, the Error Sums of Squares are slightly different for the corresponding initial equations for the groups. The R^2s of the "hourly temperatures" equations in Table 6.22 are not very different from those of the "daily temperatures" equations in Table 6.13. Further, Tables 6.23 and 6.24 show equations in which rainfall and rainfall with light variables, respectively, have been added to the "hourly" equations in Table 6.22. Addition of hourly temperature variables improved the equations in Nelson and Elgin, but not in Massachusetts. There were too few data from Canterbury to determine an effect. Even in Nelson and Elgin, however, these improvements were not greater than if daily temperature variables had been used. Overall, the added effort to record hourly temperatures does not appear justified for the purpose of predicting scald susceptibility.

General Remarks

Table 6.25 shows effects of adding variables to equations describing scald variation in Elgin and Massachusetts. The order of addition of variables is by decreasing likelihood of availability. Thus, if only harvest date were known, then only the first equation could be used; if starch were measured, then the second could be used, etc.

The Elgin equations show a clear progression of improvement as variables were added to equations. Each equation, except that adding R236, was an improvement over the one above it according to Chow's test (P=0.01). The signs of the coefficients did not change as variables were added. Some of the signs of the coefficients were not as expected, but that is not surprising when using several correlated "independent" variables. In a given year, poststorage scald does decrease as harvest date (DA) increases, even though the DA coefficient is positive. According to a great deal of previous research, increasing numbers of days of 10°C or less (D10) is associated with decreasing poststorage scald. The unexpected signs of coefficients may be attributed to year to year differences among variables. In the case of the unexpected positive sign for DA, Table 6.26 shows that overall harvest was earlier (DA was lower) in 1982 and 1983 than in 1980 and 1981, and at the same time scald was substantially lower in 1982 and 1983 than in 1980 and 1981. In the case of the unexpected positive sign for D10, Table 6.26 shows that in 1981 through 1983, D10 was lower than in 1980, while scald also was lower in those years. Interactions with other variables may well contribute to determining signs of coefficients.

The Masachusetts equations do not show such a clear progressive improvement as the Elgin equations (Table 6.25). Most of the variation in scald development can be explained simply by harvest date of the fruit. Adding variables did not always significantly improve equations in Table 6.25. In addition, one of the variables, AVG, did not have a consistent sign in all equations. Table 6.15 shows a correlation coefficient of -0.91 between D12 and AVG for 261 of the 273 cases used in the equations in Table 6.25. These two variables may nearly cancel out one another when used together in an equation. The negative coefficient for ST may be explained by the unusually high starch scores recorded in 1991 (Table 6.27) in conjunction with the low scald development. Within years, starch score correlates negatively with scald development. At any rate, these year-to-year variations in variables must be expected, and if equations can be used to predict scald effectively, the meanings of the signs of the coefficients need not be completely understood.

Logit Equations to Predict Scald

In order to identify especially scald-resistant and especially scald-susceptible lots of fruit, the variables used in Table 6.25 were used and equations were developed as was done in previous chapters. As before, approximately 85% of the data from a given data set were randomly selected to develop Logit equations; the remaining 15% were used to test equations.

Using All Cases

It was shown in Table 6.7 that attempting to describe scald variation using only harvest date without taking orchard location into account was not very successful, with the equation R^2 of only 0.20. Tables 6.28 and 6.29 show results of attempts using this previously unsuccessful method to identify especially scald-susceptible (over 60% of fruit in a lot developing scald) and especially scald-resistant (fewer than 20% of fruit in a lot developing scald) lots of fruit. The Index shown in Table 6.28 states that at least 60% of fruit picked before 10 September (northern hemisphere) or 8 February (southern hemisphere) were likely to develop scald. Table 6.2 shows that very few fruit were harvested before these dates. Table 6.28 further shows (as the data in Table 6.2 show must happen) that where predictions were incorrect, the most common incorrect placement of lots was in the category "Predicted OK" but really "Bad". This is precisely the category which would cause the most financial loss for someone using this prediction system. Fruit would be thought treatable for scald without going to extreme measures, but actually would be very likely to scald without a rigorous treatment. There were 36 lots of fruit in this underpredicted scald category. This is nearly 20% of the entire tested sample. Table 6.29 shows an attempt to identify especially scald-resistant lots of fruit. While the NSI of this equation, at 0.204, is not much better than the 0.138 NSI of the previous equation, more of the fruit were harvested after the critical harvest dates of 2 March/October. Note that this prediction equation merely states that fewer than 20% of fruit harvested after 13 October (northern hemisphere) or 13 March (southern hemisphere) will likely develop scald. Misplaced lots of fruit were equally divided between the "Good" but predicted "Not good", and the "Not good" but predicted "Good" categories. However, there were substantial area-to-area differences in tests of the equation. It worked quite well for the British Columbia, Canada data but not at all for the Elgin, South Africa data. Clearly, separate equations for separate areas would be appropriate.

If separate equations are made for each location, predictions are somewhat different. Because there was no scald on any of the 'Delicious' samples from Otago, equations could not be made for that area. Results of testing equations to identify scald-susceptible and scald-resistant lots of fruit by area are shown in Tables 6.30 and 6.31.

In Table 6.28, the critical date on which fruit, if harvested earlier, would likely be especially scald-susceptible was 8 February/10 September. Table 6.30 shows that when separate equations are made for each location, the critical dates varied. Also, the successes of the different equations were quite variable. The two equations for Elgin and High Noon, South Africa were not at all effective. The equations for other areas were better and, when tested, put more lots of fruit in correct categories than had the equation in Table 6.28.

The critical harvest date beyond which fewer than 20% of fruit were likely to scald was 2 October/March when all data were combined (Table 6.29). Critical harvest dates again varied when a separate equation was made for each area (Table 6.31). Again, the equations from the South Africa data gave meaningless results. The Table 6.31 non-South African equations were equivalent to or better than the combined equation at identifying scald-resistant lots of fruit. However, not all the equations were effective in identifying scald-resistant fruit, and there could be no prediction at all using the South African data. Clearly more information is needed to identify reliably either scald-susceptible or scald-resistant lots of fruit.

Using All Variables

Using more variables made it possible to describe more of the variation in scald development. Only the Elgin and Massachusetts data sets contained all of the variables which were measured for this study. Since harvest date alone was such a poor predictor of scald on the Elgin fruit, using more variables to identify especially scald-susceptible and scald-resistant fruit should improve the equations.

The top of Table 6.32 shows Logit equations developed separately for Elgin and Massachusetts to predict which lots of fruit in a randomly selected subset of lots were likely to be especially scald-susceptible or, alternatively, especially scald-resistant. The bottom of the table shows results of testing the equations.

Of the equations using the Elgin data, the NSI's improved substantially over those using only DA as a predictor. NSI went from zero to 0.853 for the scald-susceptible group and from zero to 0.737 for the scald-resistant group. In testing the Elgin equations, only 1 of 5 "Bad" lots of fruit was misidentified. Only 2 lots which were not scald-resistant were misidentified, and 24 of 26 "Good" lots were correctly identified. A prediction system this good would certainly be useful.

For the Massachusetts equations, improvements over using only harvest date were not as substantial as the Elgin equations had shown, but NSI improved from 0.493 to 0.587 for the equations identifying scald-susceptible lots, and from 0.331 to 0.433 for the equations identifying scald-resistant lots of fruit. In testing the equations identifying scald-susceptible fruit, many of the "Bad" lots were misidentified whether the "DA" (Table 6.30) equation or the "all variables" (Table 6.32) equation was used. Results of testing the "DA" equation were actually better than those for the "all variables" equation. The "all variables" equation did about as well as the "DA" equation in identifying scald-resistant lots of fruit. The "DA" equation missed 4 of the 28 "Good" lots and misidentified 7 of the 29 lots which had at least 20% of fruit scalding, while the "all variables" equation only missed 3 of 24 "Good" lots and misidentified 8 of 21 lots which had at least 20% of fruit developing scald. Neither Massachusetts equation did as well as the corresponding Elgin equation.

However, Table 6.32 shows results of testing equations using a random sampling of the data. What really is needed is a system for predicting scald susceptibility of fruit in a future season, based on experience of past seasons. Table 6.33, using the same data as Table 6.32, is an attempt at doing just that. Rather than use a random sampling of the data to create the Logit equations, equations were developed using the 1980-1982 data from Elgin, and the 1987-1992 data from Massachusetts. These equations were tested using the 1983 and 1993 data from Elgin and Massachusetts, respectively. The NSI's of the equations in Table 6.33 were similar to those in Table 6.32. The test results, however, were rather different. In 1983 very few fruit from Elgin developed scald. No lot of fruit exceeded 60% scald. This was correctly predicted. Only 3 of 55 lots of fruit exceeded 60% scald, but none of these 3 lots was identified. Since there was so little scald, it is hard to have confidence in the success of the predictions, especially since those few lots of fruit in which over 20% of fruit scalded were not correctly identified. In Massachusetts the distribution of scald in 1993 was over a greater range than in Elgin in 1983. Equation B correctly placed all 12 lots in which over 60% of fruit scalded, but misidentified 13 of 28 of the less scald-susceptible lots. This information could have been of value to a postharvest fruit handler. Fifteen lots of fruit could have been successfully spared aggressive antiscald treatment. Equation D was not so successful, though. No lots were predicted to develop scald in under 20% of fruit, though half of the 40 lots did end up in the "Good" category. While fruit would not have been undertreated, not much would have been gained from the information.

The difference in the test results of Tables 6.32 and 6.33 illustrate some of the differences between description and prediction models. Some of the variables vary much more from year to year than within a year. Preharvest days below 10°C in Elgin is a good example of this. Table 6.26 shows that mean number of days below 10°C from 1 January to harvest (D10) in Elgin was 12 in 1980, and 2, 7, and 6 in 1981, 1982, and 1983, respectively. Corresponding percentages of fruit developing scald were 55% in 1980, and 11, 5, and 10% for 1981, 1982, and 1983, respectively. Even if, within individual years, D10 was negatively correlated to scald, if all the data were combined, the overall correlation between D10 and scald could be positive. Using the example of Equation C of Table 6.33 to predict scald resistant lots of fruit in 1983, the D10 coefficient was negative and significant, indicating that more days at or below 10°C would reduce the Index, and move the lot toward the higher scald category. The D10 variable was also negative and significant in Equation C of Table 6.32, but since the test data came from a random subset of the equation data, they would be expected to fit the equation well. The solution to such year-to-year problems is, of course, to collect data over a period of many years. This should reduce the tendency for year-to-year covariation to be incorrectly interpreted.

Table 6.1 Number of global samples available for analyzing effects of temperature and fruit maturity on scald on 'Delicious' apples.

Area	Years	Total	With hourly temps	With starch	With starch and hourly temps
Canada, British Columbia	1990, 91, 92	213	213	213	213
New Zealand, Hawkes Bay	1987, 88, 89, 91	30	7	20	0
New Zealand, Nelson	1987, 88, 91	27	27	19	19
New Zealand, Canterbury	1987	9	9	9	9
New Zealand, Otago	1988, 89	18	0	18	0
South Africa, Elgin	1980 - 1983 (4 years)	290	290	250	250
South Africa, High Noon	1986, 87, 88	72	72	0	0
USA, Massachusetts	1986 - 1993 (8 years)	344	252	273	201
USA, West Virginia	1982 - 1989 (8 years)	38	38	0	0
USA, Washington	1987 - 1991 (5 years)	145	0	145	0
Total		1,186	908	947	692

Table 6.2 Comparisons of percent scald and harvest date of 'Delicious' apples grown in different global areas.

		Percent Scald				Harvest Date				Harvest Date as days after full bloom			
Area	N	Mean	SD	Min	Max	Mean	SD (days)	Min	Max	Mean	SD	Min	Max
Canada, British Columbia	213	37.1	31.4	0	100	01 Oct	11	27 Sep	23 Oct	N.A.[z]	N.A.	N.A.	
New Zealand, Hawkes Bay	30	30.8	37.2	0	100	16 Mar	19	9 Feb	22 Apr	N.A.	N.A.	N.A.	
New Zealand, Nelson	27	15.0	21.2	0	76	22 Mar	19	18 Feb	22 Apr	N.A.	N.A.	N.A.	
New Zealand, Canterbury	9	13.3	13.7	0	38	24 Mar	19	24 Feb	21 Apr	N.A.	N.A.	N.A.	
New Zealand, Otago	18	0.0	0.0	0	0	01 Apr	19	4 Mar	29 Apr	N.A.	N.A.	N.A.	
South Africa, Elgin	290	17.8	26.8	0	100	28 Feb	14	26 Jan	27 Mar	135.5	13.1	106	161
South Africa, High Noon	72	53.4	27.2	4	100	03 Mar	10	17 Feb	22 Mar	135.0	9.1	119	151
USA, Massachusetts	344	35.4	35.1	0	100	05 Oct	8	14 Sep	22 Oct	145.8	9.8	120	173
USA, West Virginia	38	48.0	29.8	0	100	19 Sept	9	04 Sep	07 Oct	N.A.	N.A.	N.A.	
USA, Washington	145	61.1	30.0	5	100	05 Sep	15	13 Aug	03 Oct	136.0	15.4	107	169

[z] N.A. = Data not available.

Table 6.3 Daily preharvest temperature (°C) data for global areas in which 'Delicious' scald data were taken.

		Canada, British Columbia	New Zealand, Hawkes Bay	New Zealand, Nelson	New Zealand, Canterbury	New Zealand, Otago	South Africa, Elgin	South Africa, High Noon	USA, Massachusetts	USA, West Virginia
		N=213	N=30	N=27	N=9	N=18	N=290	N=72	N=344	N=38
AVG TEMP[z]	Mean	16.6	18.7	16.8	15.1	15.8	18.6	18.7	18.3	20.9
	SD	1.5	0.9	0.7	0.7	0.9	0.2	0.9	1.1	0.9
	Min	12.9	17.0	15.3	14.0	14.3	18.1	17.5	16.5	19.4
	Max	19.9	20.1	18.6	16.1	17.1	19.0	19.9	20.6	23.0
D6[y]	Mean	10.5	2.3	1.6	6.6	23.6	0.3	0.7	10.0	2.8
	SD	8.3	2.0	3.2	6.4	13.0	0.4	0.5	4.5	2.2
	Min	0	0	0	2	6	0	0	1	0
	Max	38	12	13	19	51	1	1	20	8
D8[x]	Mean	19.7	6.5	6.4	14.1	36.9	3.4	2.8	14.6	5.1
	SD	10.8	5.3	7.4	9.3	15.9	2.7	1.7	5.7	3.5
	Min	0	1	0	6	15	0	1	2	0
	Max	48	18	29	31	65	8	6	26	13
D10[w]	Mean	30.0	12.0	17.0	23.6	52.8	12.0	15.9	21.9	9.3
	SD	11.8	9.0	11.4	12.5	17.4	6.9	4.1	7.5	4.8
	Min	4	2	1	9	27	1	10	6	0
	Max	57	32	41	45	80	23	22	33	21
D12[v]	Mean	41.0	23.4	31.4	36.7	67.7	32.7	41.3	30.1	12.3
	SD	12.7	16.5	15.1	15.4	18.3	13.6	5.4	9.5	5.5
	Min	11	4	4	17	40	11	34	10	3
	Max	67	63	58	61	96	59	52	47	24

[z] AVGTEMP = Average of daily minimum and maximum temperatures from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest.
[y] D6 = Number of days from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest in which minimum temperature recorded was as low as or lower than 6°C.
[x] D8 = Number of days from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest in which minimum temperature recorded was as low as or lower than 8°C.
[w] D10 = Number of days from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest in which minimum temperature recorded was as low as or lower than 10°C.
[v] D12 = Number of days from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest in which minimum temperature recorded was as low as or lower than 12°C.

Table 6.4 Averages of daily preharvest high temperature (°C) information for samples from global areas in which 'Delicious' scald data were taken.

		Canada, British Columbia	New Zealand, Hawkes Bay	New Zealand, Nelson	New Zealand, Canterbury	New Zealand, Otago	South Africa, Elgin	South Africa, High Noon	USA, Massachusetts	USA, West Virginia
		N=213	N=30	N=27	N=9	N=18	N=290	N=72	N=344	N=38
AVG TEMP[z]	Mean	16.6	18.7	16.8	15.1	15.8	18.6	18.7	18.3	20.9
	SD	1.5	0.9	0.8	0.7	0.9	0.2	0.9	1.1	0.9
	Min	12.9	17.0	15.3	14.0	14.3	18.1	17.5	16.5	19.4
	Max	19.9	20.1	18.6	16.1	17.1	19.0	19.9	20.6	23.0
D30[y]	Mean	7.5	3.9	0	1	7.0	6.2	10.7	9.4	13.6
	SD	3.3	2.9	0	0	2.1	2.9	3.9	4.6	5.5
	Min	1	0	0	1	5	4	4	0	4
	Max	20	8	0	1	9	15	15	16	29
D28[x]	Mean	12.4	10.5	0.4	5	14.4	11.2	17.8	14.3	20.8
	SD	3.2	3.5	0.5	0	3.5	4.6	6.0	4.1	5.1
	Min	8	6	0	5	11	4	9	6	14
	Max	27	15	1	5	18	23	26	19	36
D25[w]	Mean	22.3	26.6	3.3	5.1	29.7	27.0	35.9	30.6	33.8
	SD	6.3	9.5	1.0	0.3	1.6	8.7	9.3	3.6	5.9
	Min	12	10	1	5	26	15	22	19	22
	Max	44	38	4	6	32	51	52	35	44

[z] AVGTEMP = Average of daily minimum and maximum temperatures from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest.
[y] D30 = Number of days from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest in which maximum temperature recorded reached at least 30°C.
[x] D28 = Number of days from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest in which maximum temperature recorded reached at least 28°C.
[w] D25 = Number of days from day 215 (01 January in southern hemisphere; 03 August in northern hemisphere) to harvest in which maximum temperature recorded reached at least 25°C.

Table 6.5 Preharvest rainfall, as average mm/day, for global areas where 'Delicious' fruit were sampled.

		New Zealand, Hawkes Bay	New Zealand, Nelson	New Zealand, Canterbury	New Zealand, Otago	South Africa, Elgin	South Africa, High Noon	USA, Massachusetts
		N=26	N=27	N=9	N=18	N=270	N=72	N=344
Rain236[z]	Mean	2.90	3.19	2.97	1.97	2.17	0.33	3.88
	SD	1.55	0.95	0.39	0.39	1.61	0.19	1.46
	Min	0.69	1.75	2.33	1.45	0.03	0.03	1.16
	Max	6.16	5.13	3.48	2.84	4.96	0.59	6.54
Rain246[y]	Mean	3.12	3.20	3.26	2.12	1.84	0.41	4.09
	SD	2.23	1.58	0.56	0.47	2.26	0.25	2.35
	Min	0.13	1.11	2.40	1.61	0.06	0.05	1.28
	Max	7.74	6.25	4.03	3.20	8.45	0.83	8.37
Rain3wk[x]	Mean	3.36	3.06	2.61	1.61	1.30	0.59	3.87
	SD	2.94	2.17	1.49	1.32	1.49	0.50	2.99
	Min	0.06	0.58	0.22	0.40	0.02	0.00	0.60
	Max	9.78	6.64	4.84	4.58	5.19	1.45	10.20
August/January Rain[w]	Mean	0.86	1.59	0.63	1.75	2.07	0.13	4.53
	SD	0.29	0.61	0.00	0.51	1.63	0.08	2.08
	Min	0.64	1.03	0.63	1.25	0.78	0.03	1.45
	Max	1.37	2.48	0.63	2.25	4.68	0.23	8.14

[z] Rain236 = Average daily rainfall in mm from day 236 (22 January in southern hemisphere; 14 August in northern hemisphere) to harvest.
[y] Rain246 = Average daily rainfall in mm from day 246 (01 February in southern hemisphere; 24 August in northern hemisphere) to harvest.
[x] Rain3wk = Average daily rainfall in mm during the 3 weeks immediately preceding harvest.
[w] August/January Rain = Average daily rainfall in mm during August (northern hemisphere) or January (southern hemisphere).

Table 6.6 A global comparison of starch scores of 'Delicious' apples at harvest.

Area	N of cases	Mean Starch Score	SD	Minimum	Maximum
Canada, British Columbia	213	1.93	1.01	0.2	4.9
New Zealand, Hawkes Bay	20	1.94	0.72	1.0	3.8
New Zealand, Nelson	19	2.19	1.09	0.3	4.7
New Zealand, Canterbury	9	3.06	1.79	1.0	6.8
New Zealand, Otago	18	2.67	1.86	1.0	6.6
South Africa, Elgin	250	2.31	1.57	0.3	7.0
USA, Massachusetts	273	2.74	1.22	1.0	7.0
USA, Washington	145	1.64	0.56	1.0	3.7
Total	947	2.25	1.28	0.2	7.0

Table 6.7 Equations relating scald development to global harvest date[z] of 'Delicious' fruit, N=1186.

Equation	Percent Scald =	SS Error	R^2	Chow's F
A	$B_0 + B_1DA^z$	1057937	0.22	
B	$B_{0MA}{}^{yx} + B_{1BC} + B_{2HB} + B_{3NE} + B_{4CA} + B_{5OT} + B_{6EL} + B_{7HN} + B_{8WV} + B_{9WA} + B_{10}DA$	919222	0.32	A vs B = 9.78[w]
C	$B_0 + B_1DA_{MA} + B_2DA_{BC} + B_3DA_{HB} + B_4DA_{NE} + B_5DA_{CA} + B_6DA_{OT} + B_7DA_{EL} + B_8DA_{HN} + B_9DA_{WV} + B_{10}DA_{WA}$	967258	0.29	A vs C = 6.07
D	$B_{0MA} + B_{1BC} + B_{2HB} + B_{3NE} + B_{4CA} + B_{5OT} + B_{6EL} + B_{7HN} + B_{8WV} + B_{9WA} + B_{10}DA_{MA} + B_{11}DA_{BC} + B_{12}DA_{HB} + B_{13}DA_{NE} + B_{14}DA_{CA} + B_{15}DA_{OT} + B_{16}DA_{EL} + B_{17}DA_{HN} + B_{18}DA_{WV} + B_{19}DA_{WA}$	692245	0.49	A vs D = 34.22 B vs D = 21.24 C vs D = 25.73

[z] DA = Harvest date as days after 10 January (southern hemisphere) or 12 August (northern hemisphere).
[y] Abbreviations for areas are as follow: MA = Massachusetts, USA; BC = British Columbia, Canada; HB = Hawkes Bay, NZ; NE = Nelson, NZ; CA = Canterbury, NZ; OT = Otago, NZ; EL = Elgin, SA; HN = High Noon, SA; WV = West Virginia, USA; WA = Washington, USA.
[x] B_x's for Equation B are as follow:

Northern hemisphere		Southern hemisphere	
B_{0MA}	91	B_{2HB}	85
B_{1BC}	88	B_{3NE}	87
B_{9WV}	87	B_{4CA}	88
B_{10WA}	86	B_{5OT}	83
		B_{6EL}	68
		B_{7HN}	108

[w] All F's are significant at P=0.01.

Table 6.8 Comparisons of R^2s of equations relating scald or $e^{(\%Scald/100)}$ to harvest date[z] or ln(harvest date). N=1186 from 10 different global areas. Equations are of the form Scald variable = $B_0 + B_1DA^z$.

	Forms of dependent and independent variables:			
Constraints	Scald DA	$e^{(\%Scald/100)}$ DA	Scald ln(DA)	$e^{(\%Scald/100)}$ ln(DA)
A) Neither constant nor DA^z coefficient vary by area.	0.22	0.21	0.15	0.14
B) Constant, but not DA coefficient, allowed to vary by area.	0.32	0.30	0.25	0.23
C) DA coefficient, but not constant, allowed to vary by area.	0.29	0.26	0.25	0.23
D) Both constant and DA coefficient allowed to vary by area.	0.49	0.47	0.49	0.47

[z] Harvest date (DA) = Number of days after 10 January (southern hemisphere) or 11 or 12 August (northern hemisphere) in which fruit were harvested.

Table 6.9 Comparisons of equations relating scald development to global harvest date[z] of 'Delicious' apples. Equations are of the form Percent scald = $B_0 + B_1DA^z$, with B_0 and B_1 allowed to vary with year for each location where indicated.

Location	N	Equation A including all years together		Equation B allowing constant to vary by year		Chow's F A vs B	Equation C allowing constant and DA coef to vary by year		Chow's F A vs C	Chow's F B vs C
		Error SS	R^2	Error SS	R^2		Error SS	R^2		
British Columbia (3 yrs)	213	104180	0.50	79854	0.62	15.76^{**y}	79719	0.62	15.88**	0.09^{ns}
Hawkes Bay (4 yrs)	30	14623	0.63	11159	0.72	1.14^{ns}	7011	0.82	3.98**	2.17^{ns}
Nelson (3 yrs)	27	4373	0.62	4267	0.63	0.13^{ns}	3579	0.69	1.01^{ns}	1.01^{ns}
Elgin (4 yrs)	290	206800	0.00	80784	0.61	73.32**	34146	0.83	237.65**	64.19**
High Noon (3 yrs)	72	52506	0.00	21949	0.58	22.97**	18265	0.65	30.93**	3.33^{ns}
Massachusetts (8 yrs)	344	177980	0.58	72786	0.83	33.86**	61965	0.85	43.86**	4.09**
West Virginia (5 yrs)	33	14495	0.47	5797	0.84	4.31**	4405	0.84	6.59**	0.91^{ns}
Washington (5 yrs)	145	110650	0.14	67368	0.48	10.84**	59690	0.54	14.43**	2.17*

[z] Harvest date (DA) = Number of days after 10 January (southern hemisphere) or 12 August (northern hemisphere) at which fruit were harvested.
[y] ns = not significant at P=0.05, * = significant at P=0.05; ** = significant at P=0.01.

Table 6.10 Comparisons of equations relating scald development to global harvest date[z] of 'Delicious' apples and average preharvest temperature[y]. Equations are of the form Percent scald = $B_0 + B_1DA^z + B_2AVGTEMP^y$, with coefficients (B's) allowed to vary with year for each location where indicated.

		Equation A including all years together		Equation B allowing B_0 to vary by year			Equation C allowing B_0, B_1 and B_2 to vary by year			
Location	N	Error SS	R^2	Error SS	R^2	Chow's F A vs B	Error SS	R^2	Chow's F A vs C	Chow's F B vs C
British Columbia (3 yrs)	213	101250	0.51	75820	0.64	11.40**[x]	73486	0.65	12.85**	1.08ns
Hawkes Bay (4 yrs)	30	12208	0.70	10680	0.73	0.29ns	5165	0.87	2.73*	2.14ns
Nelson (3 yrs)	27	4366	0.63	4051	0.66	0.23ns	3105	0.73	1.22ns	0.91ns
Elgin (4 yrs)	290	173120	0.16	79774	0.61	36.14**	31405	0.85	139.39**	47.57**
High Noon (3 yrs)	72	46707	0.11	20311	0.61	13.65**	11036	0.79	34.88**	8.82**
Massachusetts (6 yrs)	312	129290	0.64	67616	0.81	17.88**	53405	0.85	27.85**	5.22**
West Virginia (5 yrs)	33	14259	0.48	4345	0.84	3.42**	2911	0.89	5.85**	0.74ns

[z] Harvest date (DA) = Number of days after 10 January (southern hemisphere) or 12 August (northern hemisphere) at which fruit were harvested.

[y] AVGTEMP = Average of daily maximum and minimum temperatures from 03 August (01 January in southern hemisphere) to harvest.

[x] ns = not significant at P=0.05, * = significant at P=0.05; ** = significant at P=0.01.

Table 6.11 Comparisons of equations relating scald development to global harvest date[z] and starch score[y] of 'Delicious'. Equations are of the form Percent scald = $B_0 + B_1DA^z + B_2ST^y$, with coefficients (B's) allowed to vary with year for each location where indicated.

Location	N	Equation A including all years together		Equation B allowing B_0 to vary by year		Chow's F A vs B	Equation C allowing B_0, B_1 and B_2 to vary by year		Chow's F A vs C	Chow's F B vs C
		Error SS	R^2	Error SS	R^2		Error SS	R^2		
British Columbia (3 yrs)	213	94264	0.55	78137	0.63	7.02**x	76560	0.63	7.86**	0.70ns
Hawkes Bay (3 yrs)	20	8014	0.69	4490	0.83	1.44ns	1300	0.95	9.47**	4.50*
Nelson (2 yrs)	19	2329	0.62	2319	0.62	0.02ns	2287	0.62	0.08ns	0.06ns
Canterbury (1 yr)	9						332	0.78		
Elgin (4 yrs)	250	154160	0.20	32117	0.83	100.49**	22716	0.88	153.02**	10.94**
Massachusetts (6 yrs)	261	100930	0.60	56746	0.78	12.61**	49161	0.81	17.06**	2.50**
Washington (5 yrs)	145	102970	0.20	66658	0.48	5.90**	55874	0.57	9.13**	2.09*

[z] Harvest date (DA) = Number of days after 10 January (southern hemisphere) or 12 August (northern hemisphere) at which fruit were harvested.
[y] ST = Starch score at harvest.
[x] ns = not significant at P=0.05, * = significant at P=0.05; ** = significant at P=0.01.

Table 6.12 Comparisons of equations relating scald development to global harvest date[z], average preharvest temperature[y], and starch score[x] of 'Delicious'. Equations are of the form Percent scald = $B_0 + B_1DA^z + B_2AVG^y + B_3ST^x$, with coefficients ($B_x$'s) allowed to vary with year for each location where indicated.

Percent Scald =		British Columbia	Hawkes Bay	Nelson	Canter-bury	Elgin	Mass.	All cases by area[w]	All cases
		N=213; Yrs=3	N=20; Yrs=3	N=19; Yrs=2	N=9; Yrs=1	N=250; Yrs=4	N=261; Yrs=6	N=772	N=772
A) $B_0 + B_1DA$	Error SS	104180	8174	2377	369	193810	101610	559400	606250
	R^2	0.50	0.68	0.61	0.75	0.00	0.60	0.23	0.17
B) $B_0 + B_1DA + B_2AVG$	Error SS	102250	7728	2279	337	171340	95421	502290	601350
	R^2	0.51	0.70	0.63	0.78	0.12	0.63	0.31	0.18
C) $B_0 + B_1DA + B_2ST$	Error SS	94264	8014	2329	332	154160	100930	556870	599010
	R^2	0.55	0.69	0.62	0.78	0.20	0.60	0.24	0.18
D) $B_0 + B_1DA + B_2ST + B_3AVG$	Error SS	92252	7727	2276	281	135940	92846	492270	590520
	R^2	0.56	0.70	0.63	0.81	0.30	0.64	0.32	0.19
E) Equation D) with B_0 allowed to vary by year	Error SS	75141	4314	2242		31740	56737	256678	
	R^2	0.64	0.83	0.63		0.84	0.78	0.65	
F) Equation D) with all B's allowed to vary by year	Error SS	70566	475	1824		21004	45820		
	R^2	0.66	0.98	0.70		0.89	0.82		

[z] Harvest date (DA) = Number of days after 10 January (southern hemisphere) or 12 August (northern hemisphere) at which fruit were harvested.
[y] AVG = Average of daily maximum and minimum temperatures from 03 August (01 January in southern hemisphere) to harvest.
[x] ST = Starch score at harvest.
[w] B_0 allowed to vary by area in equations in this column.

Table 6.13 OLS equations relating poststorage scald development to global harvest date (DA)[z] and starch score (ST)[y], average preharvest temperature (AVG)[x], and preharvest cool temperature variables (Dx)[w].

Area	Percent Scald = $B_0 + B_1DA + B_2ST + B_3AVG$	Error SS	R^2	Significance at P=0.05 of: DA	ST	AVG	Dx
All areas[v] N=772		515590	0.32	-	-	+	
	+ B_4D6	475930	0.37	-	-	ns	-
	+ B_5D8	502730	0.34	-	-	+	-
	+ B_6D10	515550	0.32	-	-	+	ns
	+ B_7D12	514930	0.32	-	-	+	ns
British Columbia 3 Years N=213		92252	0.56	-	-	+	
	+ B_4D6	83515	0.60	-	-	-	-
	+ B_5D8	88863	0.57	-	-	ns	-
	+ B_6D10	92173	0.56	-	-	ns	ns
	+ B_7D12	89094	0.57	-	-	+	+
Hawkes Bay 3 Years N=20		7727	0.70	-	ns	ns	
	+ B_4D6	7253	0.72	-	ns	ns	ns
	+ B_5D8	4678	0.82	-	ns	+	+
	+ B_6D10	3578	0.86	-	ns	+	+
	+ B_7D12	5650	0.78	-	ns	+	+
Nelson 2 Years N=19		2276	0.63	ns	ns	ns	
	+ B_4D6	1394	0.77	ns	ns	+	+
	+ B_5D8	1303	0.79	ns	-	+	+
	+ B_6D10	1026	0.83	-	ns	+	+
	+ B_7D12	1923	0.68	-	ns	ns	ns
Canterbury 1 Year N=9		281	0.81	ns	ns	ns	
	+ B_4D6	53	0.96	ns	-	+	+
	+ B_5D8	41	0.97	+	-	+	+
	+ B_6D10	95	0.94	ns	ns	+	+
	+ B_7D12	67	0.96	ns	ns	+	+
Elgin 4 Years N=250		135940	0.29	+	-	+	
	+ B_4D6						
	+ B_5D8	59958	0.69	+	-	+	+
	+ B_6D10	39594	0.80	+	-	+	+
	+ B_7D12	91144	0.53	+	-	+	+
Mass 6 Years N=261		92846	0.64	-	+	-	
	+ B_4D6	92765	0.64	-	+	-	ns
	+ B_5D8	92348	0.64	-	+	-	ns
	+ B_6D10	92846	0.64	-	+	-	ns
	+ B_7D12	90969	0.64	-	+	ns	+

[z] Harvest date (DA) = Days after 10 January (southern hemisphere) or 12 August (northern hemisphere) before fruit were harvested.
[y] ST = Starch score at harvest.
[x] AVG = Average of daily maximum and minimum temperatures from 03 August (01 January in southern hemisphere) to harvest.
[w] Dx = Number of preharvest days with temperature recorded at or below x°C, (x= 6, 8, 10, or 12) beginning 01 January in the southern hemisphere or beginning 03 August in the northern hemisphere.
[v] Equations in this group have a different B_0 for each area.

Table 6.14 Correlations among global poststorage scald development on 'Delicious' apples, harvest date (DA)[z], harvest starch score (ST)[y], average preharvest temperature (AVG)[x], preharvest days at or below x°C, where x=6, 8, 10, or 12 (Dx)[w], and days with temperatures at or above y during the week before harvest, where y=30, 28, or 25 (DyW).

Factor	Correlation coefficient (r) if N=772 observations taken from six global locations									
DA	-0.41	1.00								
ST	-0.33	+0.60	1.00							
AVG	+0.21	-0.33	-0.02	1.00						
D6	-0.25	+0.36	+0.21	-0.71	1.00					
D8	-0.20	+0.40	+0.19	-0.81	+0.94	1.00				
D10	-0.15	+0.46	+0.19	-0.83	+0.87	+0.96	1.00			
D12	-0.24	+0.53	+0.20	-0.85	+0.73	+0.87	+0.93	1.00		
D30W	-0.08	+0.07	+0.23	+0.29	-0.37	-0.36	-0.33	-0.23	1.00	
D28W	-0.07	-0.05	+0.12	+0.39	-0.47	-0.48	-0.49	-0.37	+0.79	1.00
D25W	+0.05	-0.22	+0.04	+0.63	-0.59	-0.61	-0.62	-0.54	+0.57	+0.71
	Scald	DA	ST	AVG	D6	D8	D10	D12	D30W	D28W

Factor	Correlation coefficient (r) if N=161 observations taken from Massachusetts over a period of 6 years									
DA	-0.78	1.00								
ST	-0.28	+0.42	1.00							
AVG	+0.42	-0.68	-0.10	1.00						
D6	-0.73	+0.91	+0.21	-0.64	1.00					
D8	-0.71	+0.95	+0.23	-0.76	+0.91	1.00				
D10	-0.64	+0.87	+0.11	-0.85	+0.83	+0.95	1.00			
D12	-0.52	+0.79	+0.07	-0.91	+0.71	+0.89	+0.97	1.00		
D30W	+0.14	-0.18	+0.00	+0.16	-0.26	-0.22	-0.21	-0.19	1.00	
D28W	+0.59	-0.61	-0.24	+0.30	-0.57	-0.54	-0.48	-0.40	+0.42	1.00
D25W	+0.17	-0.20	+0.08	+0.51	-0.30	-0.28	-0.29	-0.32	-0.03	+0.26
	Scald	DA	ST	AVG	D6	D8	D10	D12	D30W	D28W

Factor	Correlation coefficient (r) if N=40 observations taken from Massachusetts in 1993									
DA	-0.947	1.000								
ST	-0.808	+0.827	1.000							
AVG	+0.974	-0.999	-0.828	1.000						
D6	-0.915	+0.976	+0.810	-0.974	1.000					
D8	-0.925	+0.983	+0.817	-0.982	+0.999	1.000				
D10	-0.943	+0.996	+0.832	-0.994	+0.991	+0.995	1.000			
D12	-0.941	+0.998	+0.827	-0.996	+0.987	+0.933	+0.999	1.000		
D30W	N.A.[v]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
D28W	+0.413	-0.413	-0.398	+0.403	-0.412	-0.436	-0.433	-0.428	N.A.	1.000
D25W	+0.415	-0.347	-0.388	+0.345	-0.260	-0.298	-0.335	-0.335	N.A.	0.880
	Scald	DA	ST	AVG	D6	D8	D10	D12	D30W	D28W

[z] Harvest date (DA) = Days after 10 January (southern hemisphere) or 12 August (northern hemisphere) fruit were harvested.
[y] ST = Starch score at harvest.
[x] AVG = Average of daily maximum and minimum temperatures from 03 August (01 January in southern hemisphere) to harvest.
[w] Dx = Number of preharvest days with temperature recorded at or below x°C (where x=6, 8, 10, or 12), beginning 01 January in the southern hemisphere or beginning 03 August in the northern hemisphere.
[v] N.A. = Not applicable, since temperatures did not reach 30°C during the harvest period at the Massachusetts site in 1993.

Table 6.15 OLS equations relating poststorage scald development in HRC-grown (Massachusetts) 'Delicious' fruit from 1993 to harvest date (DA)[z] and starch score (ST)[y], average preharvest temperature (AVG)[x], preharvest days at or below 12°C (D12)[w], and days at or above 25°C in the week before harvest (D25W). N=40.

Percent Scald =	Error SS	R^2	Significance at P=0.05 of:				
			DA	ST	AVG	D12	D25W
$B_0 + B_1DA + B_2ST + B_3AVG + B_4D12 + B_5D25W$	4673	0.91	ns	ns	ns	ns	ns
$B_0 + B_1DA + B_2ST + B_3AVG + B_4D12$	5954	0.90	ns	ns	ns	ns	
$B_0 + B_1DA + B_2ST + B_3AVG + B_5D25W$	4766	0.91	ns	ns	ns		ns
$B_0 + B_1DA + B_2ST + B_4D12 + B_5D25W$	4674	0.91	–	ns		ns	ns
$B_0 + B_1DA + B_3AVG + B_4D12 + B_5D25W$	4721	0.91	ns		ns	ns	ns
$B_0 + B_2ST + B_3AVG + B_4D12 + B_5D25W$	4806	0.91		ns	ns	ns	ns
$B_0 + B_1DA + B_2ST$	5138	0.90	–	ns			
$B_0 + B_1DA + B_3AVG$	5218	0.90	ns		ns		
$B_0 + B_1DA + B_4D12$	5065	0.90	–			ns	
$B_0 + B_1DA + B_5D25W$	4808	0.91	–				+
$B_0 + B_2ST + B_3AVG$	5156	0.90		ns	+		
$B_0 + B_2ST + B_4D12$	5644	0.89		ns		–	
$B_0 + B_2ST + B_5D25W$	17037	0.66		–			ns
$B_0 + B_3AVG + B_4D12$	5220	0.90			+	ns	
$B_0 + B_3AVG + B_5D25W$	4840	0.90			+		+
$B_0 + B_4D12 + B_5D25W$	5216	0.90				–	+
$B_0 + B_1DA$	5237	0.90	–				
$B_0 + B_2ST$	17652	0.65		–			
$B_0 + B_3AVG$	5244	0.90			+		
$B_0 + B_4D12$	5786	0.89				–	
$B_0 + B_5D25W$	42074	0.17					+

[z] Harvest date (DA) = Days after 10 January (southern hemisphere) or 12 August (northern hemisphere) fruit were harvested.
[y] ST = Starch score at harvest.
[x] AVG = Average of daily maximum and minimum temperatures from 03 August to harvest.
[w] D12 = Number of preharvest days with temperature recorded at or below 12°C, beginning 03 August.

Table 6.16 Information about global preharvest high temperatures.

		All areas	British Columbia	Hawkes Bay	Nelson	Canter bury	Elgin	Mass
		N=772	N=213	N=20	N=19	N=9	N=250	N=261
D30W[z]	Mean	0.22	0.01	0.05	0	0.11	0.64	0.02
	SD	0.55	0.15	0.22	0	0.33	0.80	0.14
	Minimum	0	0	0	0	0	0	0
	Maximum	3	2	1	0	1	3	1
D28W[y]	Mean	0.63	0.08	0.30	0	0.11	1.74	0.10
	SD	1.20	0.39	0.47	0	0.33	1.56	0.30
	Minimum	0	0	0	0	0	0	0
	Maximum	5	3	1	0	1	5	1
D25W[x]	Mean	1.99	0.78	1.75	0.11	0.22	4.02	1.25
	SD	2.04	1.30	1.92	0.32	0.44	1.67	1.38
	Minimum	0	0	0	0	0	1	0
	Maximum	7	6	6	1	1	7	4

[z] D30W = Number of days with temperatures reaching or exceeding 30°C in the week immediately preceding harvest.
[y] D28W = Number of days with temperatures reaching or exceeding 28°C in the week immediately preceding harvest.
[x] D25W = Number of days with temperatures reaching or exceeding 25°C in the week immediately preceding harvest.

Table 6.17 OLS equations relating poststorage scald development to global harvest date (DA)[z] and starch score (ST)[y], average preharvest temperature (AVG)[x], preharvest days at or below 10°C (D10), and three different high temperature variables (DxW)[w].

Area	Percent Scald = $B_0 + B_1DA + B_2ST + B_3AVG + B_4D10$	Error SS	R^2	Significance at P=0.05 of: DA	ST	AVG	D10	DxW
All areas[v] N=772		492030	0.32	-	-	+	ns	
	$+ B_5D30W$	487700	0.33	-	-	+	ns	+
	$+ B_6D28W$	490550	0.33	-	-	+	ns	ns
	$+ B_7D25W$	489160	0.33	-	-	+	ns	+
British Columbia 3 Years N=213		92175	0.56	-	-	ns	ns	
	$+ B_5D30W$	91990	0.56	-	-	ns	ns	ns
	$+ B_6D28W$	92175	0.56	-	-	ns	ns	ns
	$+ B_7D25W$	91294	0.56	-	-	ns	ns	ns
Hawkes Bay 3 Years N=20		3543	0.86	-	ns	+	+	
	$+ B_5D30W$	3125	0.88	-	ns	+	+	ns
	$+ B_6D28W$	2757	0.89	-	ns	+	+	-
	$+ B_7D25W$	3220	0.88	-	ns	+	+	ns
Nelson 2 Years N=19		1039	0.83	-	ns	+	+	
	$+ B_5D30W$	Preharvest temp never reached 30°C						
	$+ B_6D28W$	Preharvest temp never reached 28°C						
	$+ B_7D25W$	970	0.84	-	ns	+	+	ns
Canterbury 1 Year N=9		95	0.94	ns	ns	+	+	
	$+ B_5D30W$	29	0.98	+	ns	+	ns	+
	$+ B_6D28W$	29	0.98	+	ns	+	ns	+
	$+ B_7D25W$	69	0.95	ns	ns	+	ns	ns
Elgin 4 Years N=250		39594	0.80	+	-	+	+	
	$+ B_5D30W$	39504	0.80	+	-	+	+	ns
	$+ B_6D28W$	39592	0.80	+	-	+	+	ns
	$+ B_7D25W$	37415	0.81	+	-	+	+	-
Mass 6 Years N=261		92815	0.64	-	+	-	ns	
	$+ B_5D30W$	92815	0.64	-	+	-	ns	ns
	$+ B_6D28W$	89279	0.65	-	+	-	ns	+
	$+ B_7D25W$	89668	0.65	-	+	-	ns	+

[z] Harvest date (DA) = Days after 10 January (southern hemisphere) or 12 August (northern hemisphere) before fruit were harvested.
[y] ST = Starch score at harvest.
[x] AVG = Average of daily maximum and minimum temperatures from 03 August (01 January in southern hemisphere) to harvest.
[w] DxW = Number of preharvest days with temperature recorded at or above x°C, (x= 30, 28, or 25) beginning 01 January in the southern hemisphere or beginning 03 August in the northern hemisphere.
[v] Equations in this group have a different B_0 for each area.

Table 6.18 Comparisons of global preharvest rainfall and its relationships with poststorage scald development on 'Delicious' apples (SCALD), harvest date (DA), harvest starch score (ST), and average preharvest temperature (AVG) by area.

	Hawkes Bay	Nelson	Canterbury	Otago	Elgin	Massachusetts
	3 Yrs	2 Yrs	1 Yr	2 Yrs	4 Yrs	6 Yrs
	N=20	N=19	N=9	N=18	N=230	N=261
Mean ± SD R236[z]	3.2 ± 1.6	3.7 ± 0.6	3.0 ± 0.4	2.0 ± 0.4	2.5 ± 1.5	4.1 ± 1.4
Mean ± SD R246[y]	3.4 ± 2.4	4.0 ± 1.1	3.3 ± 0.6	2.1 ± 0.5	2.1 ± 2.4	4.3 ± 2.3
Mean ± SD R3WK[x]	3.7 ± 3.2	3.8 ± 2.2	2.6 ± 1.5	1.6 ± 1.3	1.4 ± 1.6	3.9 ± 2.8
	Correlation coefficients (r)					
R236 vs SCALD	-0.10	+0.00	+0.65	N/A[w]	-0.17	-0.39
R246 vs SCALD	-0.11	+0.11	+0.76	N/A[w]	-0.01	-0.12
R3WK vs SCALD	-0.03	+0.27	+0.80	N/A[w]	-0.07	-0.09
R236 vs DA	+0.48	+0.13	-0.90	-0.65	-0.26	+0.35
R246 vs DA	+0.47	+0.04	-0.95	-0.74	-0.40	+0.06
R3WK vs DA	+0.22	-0.24	-0.94	-0.60	-0.42	-0.03
R236 vs ST	+0.04	+0.19	-0.86	-0.49	-0.26	+0.03
R246 vs ST	+0.01	+0.22	-0.87	-0.61	-0.15	+0.04
R3WK vs ST	-0.18	-0.28	-0.82	-0.41	-0.23	+0.17
R236 vs AVG	-0.13	+0.17	+0.91	+0.59	+0.14	-0.57
R246 vs AVG	-0.09	+0.35	+0.96	+0.73	-0.44	-0.49
R3WK vs AVG	-0.12	+0.36	+0.94	+0.53	-0.39	-0.31

[z] R236 = Average daily rainfall, in mm, from day 236 (22 January in the southern hemisphere; 23 or 24 August in the northern hemisphere) to harvest.
[y] R246 = Average daily rainfall, in mm, from day 246 (01 February in the southern hemisphere; 02 or 03 September in the northern hemisphere) to harvest.
[x] R3WK = Average daily rainfall, in mm, during the 3 weeks immediately preceding harvest.
[w] There was no scald on Otago Delicious.

Table 6.19 OLS equations adding a factor for rainfall to previous global equations describing scald variation in 'Delicious' apple samples.

	Percent Scald = $B_0 + B_1DA + B_2ST + B_3AVG$	Error SS	R^2	Significance at P=0.05 of:			
				DA	ST	AVG	Rain
All areas[y] N=539		359380	0.27	-	-	+	
	$+ B_4R236$[z]	340210	0.31	-	-	+	-
	$+ B_5R246$[z]	359320	0.27	-	-	+	ns
	$+ B_6R3WK$[z]	359090	0.27	-	-	+	ns
Hawkes Bay 3 Yrs N=20		7727	0.70	-	ns	ns	
	$+ B_4R236$	4105	0.84	-	+	ns	+
	$+ B_5R246$	4370	0.83	-	+	ns	+
	$+ B_6R3WK$	6811	0.74	-	ns	ns	ns
Nelson 2 Yrs N=19		2276	0.63	ns	ns	ns	
	$+ B_4R236$	2268	0.63	ns	ns	ns	ns
	$+ B_5R246$	2246	0.63	ns	ns	ns	ns
	$+ B_6R3WK$	2256	0.63	ns	ns	ns	ns
Canterbury 1 Yr N=9		281	0.81	ns	ns	ns	
	$+ B_4R236$	93	0.94	ns	ns	+	-
	$+ B_5R246$	123	0.92	ns	ns	ns	-
	$+ B_6R3WK$	251	0.83	ns	ns	ns	ns
New Zealand N=48 (combines 3 groups above)		12650	0.66	-	+	+	
	$+ B_4R236$	11311	0.69	-	+	+	+
	$+ B_5R246$	11696	0.68	-	+	+	+
	$+ B_6R3WK$	12299	0.67	-	+	+	ns
Elgin 4 yrs N=230		131210	0.31	+	-	+	
	$+ B_4R236$	104520	0.45	ns	-	+	-
	$+ B_5R246$	123360	0.35	+	-	+	+
	$+ B_6R3WK$	123190	0.35	+	-	+	+
Mass 6 Yrs N=261		92846	0.64	-	+	-	
	$+ B_4R236$	78552	0.69	-	+	-	-
	$+ B_5R246$	77998	0.69	-	+	-	-
	$+ B_6R3WK$	75148	0.70	-	+	-	-

[z] Rainfall abbreviations, R236, R246, and R3WK are as in Table 6.18. Other abbreviations are as in Table 6.17.
[y] B_0 varies by area.

Table 6.20 OLS equations adding a factor for light to previous global equations describing scald variation in 'Delicious' samples.

	Percent Scald = $B_0 + B_1DA + B_2ST + B_3AVG + B_4R236$	Error SS	R^2	Significance at P=0.05 of:								
				DA	ST	AVG	R236	D10	D12	Dx[y]	Sun El	Sun MA
Elgin 4 Yrs N=230	$+ B_5D10$	31851	0.83	ns	–	+	+	+				
	$+ B_5D10 + B_6S236$[z]	30580	0.84	ns	–	+	ns	+			–	
	$+ B_5D10 + B_7S246$[z]	28528	0.85	ns	–	+	+	+			–	
	$+ B_5D10 + B_8S1WK$[z]	30366	0.84	ns	–	+	+	+			–	
Mass 7 Yrs N=273	$+ B_5D12$	96649	0.66	–	+	–	–		+			
	$+ B_5D12 + B_6S236$[z]	96508	0.66	–	+	ns	–		+			ns
	$+ B_5D12 + B_7S246$[z]	84690	0.70	–	+	+	–		+			–
	$+ B_5D12 + B_8S1WK$[z]	95369	0.66	–	+	–	–		+			–
Both areas N=503	$+ B_5Dx$[y]	332240	0.32	–	–	+	–			+		
	$+ B_5Dx + B_6S236$[z]	239240	0.51	–	ns	+	–			+	–	–
	$+ B_5Dx + B_7S246$[z]	180930	0.63	–	–	+	–			+	–	–
	$+ B_5Dx + B_8S1WK$[z]	320230	0.34	–	–	+	–			+	ns	–

[z] Light abbreviations, S236, S246, and S1WK are as follow:
S236 = Average daily light score from day 236 (22 January in the southern hemisphere; 24 August in the northern hemisphere) to harvest.
S246 = Average daily light score from day 246 (01 February in the southern hemisphere; 03 September in the northern hemisphere) to harvest.
S1WK = Average daily light score during the week immediately preceding harvest.
Other abbreviations are as in Tables 6.17 and 6.18.
[y] Dx = D10 for Elgin; D12 for Massachusetts.

Table 6.21 Correlation coefficients relating global preharvest light scores to various factors associated with poststorage scald development on 'Delicious' apples.

Name	Correlation coefficient (r)					
	Elgin N=230			Massachusetts N=273		
Scald	+0.22	+0.02	+0.21	-0.28	-0.33	-0.22
DA[z]	-0.22	-0.27	+0.05	+0.24	-0.25	+0.27
ST	-0.00	-0.10	-0.01	+0.16	+0.01	-0.13
AVG	-0.50	-0.28	+0.39	+0.37	+0.33	-0.25
D10	+0.60	+0.19	+0.28	+0.06	+0.17	+0.35
D12	+0.65	+0.41	+0.27	-0.04	+0.03	+0.33
R236	-0.55	+0.03	-0.15	-0.30	-0.38	-0.06
	S236	S246	S1WK	S236	S246	S1WK

[z] Abbreviations are as in Table 6.20.

Table 6.22 OLS equations relating poststorage scald development on 'Delicious' apples to global harvest date (DA)[z] and starch score (ST)[y], average preharvest temperature (AVG)[x], and preharvest cool temperature variables (Hx)[w].

Area	Percent Scald = $B_0 + B_1DA + B_2ST + B_3AVG$	Error SS	R^2	Significance at P=0.05 of:			
				DA	ST	AVG	Hx
All areas[v] N=692		465050	0.31	-	-	+	
	+ B_4H6	447980	0.34	-	-	+	-
	+ B_5H8	446350	0.34	ns	-	+	-
	+ B_6H10	449460	0.34	ns	-	+	-
	+ B_7H12	453810	0.33	ns	-	+	-
British Columbia 3 Years N=213		92229	0.56	-	-	+	
	+ B_4H6	90657	0.57	-	-	ns	-
	+ B_5H8	89846	0.57	-	-	ns	-
	+ B_6H10	90307	0.57	-	-	ns	-
	+ B_7H12	91901	0.56	-	-	ns	ns
Nelson 2 Years N=19		2278	0.63	ns	ns	ns	
	+ B_4H6	1653	0.73	ns	ns	ns	+
	+ B_5H8	1236	0.80	ns	-	+	+
	+ B_6H10	1072	0.82	ns	-	+	+
	+ B_7H12	1082	0.82	-	ns	+	+
Canterbury 1 Year N=9		281	0.81	ns	ns	ns	
	+ B_4H6	44	0.97	ns	ns	ns	+
	+ B_5H8	35	0.98	ns	ns	ns	+
	+ B_6H10	62	0.96	ns	ns	ns	+
	+ B_7H12	51	0.97	ns	ns	+	+
Elgin 4 Years N=250		137510	0.29	+	-	+	
	+ B_4H6						
	+ B_5H8	55220	0.72	+	-	+	+
	+ B_6H10	39354	0.80	+	-	+	+
	+ B_7H12	46128	0.76	+	-	+	+
Mass 6 Years N=201		81394	0.64	-	+	-	
	+ B_4H6	81386	0.64	-	+	-	ns
	+ B_5H8	80162	0.65	-	+	ns	+
	+ B_6H10	81330	0.64	-	+	ns	ns
	+ B_7H12	81360	0.64	-	+	-	ns

[z] Harvest date (DA) = Days after 10 January (southern hemisphere) or 12 August (northern hemisphere) fruit were harvested.
[y] ST = Starch score at harvest.
[x] AVG = Average of daily maximum and minimum temperatures from 03 August (northern hemisphere) or 01 January (southern hemisphere) to harvest.
[w] Hx = Number of preharvest hours with temperature recorded at or below x°C, beginning 01 January in the southern hemisphere or beginning 03 August in the northern hemisphere.
[v] Equations in this group have a different B_0 for each area.

Table 6.23 OLS equations relating poststorage scald development on 'Delicious' apples to global harvest date (DA)[z] and starch score (ST)[y], average preharvest temperature (AVG)[x], preharvest cool temperature variables (Hx)[w], and rainfall (R236)[v].

Area	Percent Scald = B_0 + B_1DA + B_2ST + B_3AVG + B_8R236	Error SS	R^2	Significance at P=0.05 of:				
				DA	ST	AVG	R236	Hx
All areas[u] N=479		326810	0.27	ns	-	+	-	
	+ B_4H6	308840	0.31	ns	-	+	-	-
	+ B_5H8	300850	0.32	+	-	+	-	-
	+ B_6H10	306990	0.31	+	-	+	-	-
	+ B_7H12	308390	0.31	+	-	+	-	-
Nelson 2 Years N=19		2270	0.63	ns	ns	ns	ns	
	+ B_4H6	1558	0.74	ns	ns	ns	ns	+
	+ B_5H8	1098	0.82	ns	-	ns	ns	+
	+ B_6H10	949	0.84	ns	-	+	ns	+
	+ B_7H12	831	0.86	-	ns	+	+	+
Canterbury 1 Year N=9		93	0.94	ns	ns	+	-	
	+ B_4H6	31	0.98	ns	ns	+	ns	ns
	+ B_5H8	27	0.98	ns	ns	+	ns	ns
	+ B_6H10	42	0.97	ns	ns	+	ns	ns
	+ B_7H12	42	0.97	ns	ns	+	ns	ns
Elgin 4 Years N=250		129870	0.33	+	-	+	-	
	+ B_4H6							
	+ B_5H8	51915	0.73	+	-	+	+	+
	+ B_6H10	386658	0.80	+	-	+	+	+
	+ B_7H12	460073	0.76	+	-	+	ns	+
Mass 6 Years N=201		55491	0.76	-	+	-	-	
	+ B_4H6	55457	0.76	-	+	-	-	ns
	+ B_5H8	55480	0.76	-	+	-	-	ns
	+ B_6H10	54011	0.76	-	+	-	-	-
	+ B_7H12	51024	0.78	-	+	-	-	-

[z] Harvest date (DA) = Days after 10 January (southern hemisphere) or 12 August (northern hemisphere) fruit were harvested.
[y] ST = Starch score at harvest.
[x] AVG = Average of daily maximum and minimum temperatures from 03 August (01 January in southern hemisphere) to harvest.
[w] Hx = Number of preharvest hours with temperature recorded at or below x^{o}C, beginning 01 January in the southern hemisphere or beginning 03 August in the northern hemisphere.
[v] R236 = Average daily rainfall from Day 236 (22 January in southern hemisphere; 24 August in northern hemisphere) to harvest.
[u] Equations in this group have a different B_0 for each area.

Table 6.24 OLS equations relating poststorage scald development on 'Delicious' apples to global harvest date (DA)[z] and starch score (ST)[y], average preharvest temperature (AVG)[x], preharvest cool temperature variables (Hx)[w], rainfall (R236)[v], and light (S246)[u].

Area	Percent Scald = $B_0 + B_1DA + B_2ST + B_3AVG + B_8R236 + B_9S246$	Error SS	R^2	Significance at P=0.05 of: DA	ST	AVG	R236	S246 El	S246 MA	Hx
Both areas[t] N=431		212140	0.50	ns	–	+	–	ns	–	
	+ B_4H6	208720	0.51	ns	–	+	–	ns	–	+
	+ B_5H8	201940	0.53	ns	–	+	–	ns	–	+
	+ B_6H10	186250	0.56	–	–	+	–	ns	–	+
	+ B_7H12	180760	0.58	–	–	+	–	–	–	+
Elgin 4 Years N=230		109380	0.42	+	–	+	–	+		
	+ B_4H6									
	+ B_5H8	49612	0.74	+	–	+	+	ns		+
	+ B_6H10	33971	0.82	+	–	+	ns	–		+
	+ B_7H12	31302	0.84	ns	–	+	–	–		+
Mass 5 Years N=201		47269	0.79	–	+	+	–	–		
	+ B_4H6	47013	0.79	–	+	+	–	–		ns
	+ B_5H8	46390	0.80	–	+	+	–	–		+
	+ B_6H10	46869	0.79	–	+	+	–	–		ns
	+ B_7H12	47256	0.79	–	+	+	–	–		ns

[z] Harvest date (DA) = Days after 10 January (southern hemisphere) or 12 August (northern hemisphere) fruit were harvested.
[y] ST = Starch score at harvest.
[x] AVG = Average of daily maximum and minimum temperatures from 03 August (01 January in southern hemisphere) to harvest.
[w] Dx = Number of preharvest hours with temperature recorded at or below x°C, beginning 01 January in the southern hemisphere or beginning 03 August in the northern hemisphere.
[v] R236 = Average daily rainfall in mm from Day 236 (22 January in southern hemisphere; 24 August in northern hemisphere) to harvest.
[u] S246 = Average daily light score from Day 246 (01 February in southern hemisphere; 03 September in northern hemisphere) to harvest.
[t] Equations in this group have different B_0 and B_9 for each area.

Table 6.25 Equations with progressions of added variables for Elgin and Massachusetts data.

	Percent scald =	Error SS	R^2	Significance of B_x at P = 0.05 for:					
				DA[z]	ST	AVG	Dx	R236	S246
Elgin N=230	$B_0 + B_1DA$	189000	0.01	ns					
	$B_0 + B_1DA + B_2ST$	151680	0.20	+	-				
	$B_0 + B_1DA + B_2ST + B_3AVG$	131210	0.31	+	-	+			
	$B_0 + B_1DA + B_2ST + B_3AVG + B_4D10$	32562	0.83	+	-	+	+		
	$B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236$	31851	0.83	+	-	+	+	-	
	$B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246$	28528	0.85	+	-	+	+	-	-
Mass N=273	$B_0 + B_1DA$	118150	0.58	-					
	$B_0 + B_1DA + B_2ST$	117910	0.58	-	ns				
	$B_0 + B_1DA + B_2ST + B_3AVG$	108210	0.62	-	+	-			
	$B_0 + B_1DA + B_2ST + B_3AVG + B_4D12$	105060	0.63	-	+	ns	+		
	$B_0 + B_1DA + B_2ST + B_3AVG + B_4D12 + B_5R236$	96660	0.66	-	+	-	+	-	
	$B_0 + B_1DA + B_2ST + B_3AVG + B_4D12 + B_5R236 + B_6S246$	84655	0.70	-	+	+	+	-	-
		Expected sign:		-	-	+	-	?	?

[z] Abbreviations are as in Table 6.20.

Table 6.26 Yearly means of scald and other selected variables from Elgin, SA.

Variable	Year	N	Mean	SD
Scald	1980	60	54.93	37.92
	1981	75	10.93	11.65
	1982	40	5.45	3.14
	1983	55	9.89	5.44
DA	1980	60	59.50	10.68
	1981	75	54.00	9.97
	1982	40	46.50	11.11
	1983	55	45.09	11.05
ST	1980	60	3.31	2.35
	1981	75	2.18	0.80
	1982	40	2.07	1.23
	1983	55	2.25	0.97
AVG	1980	60	19.17	0.09
	1981	75	19.12	0.06
	1982	40	18.53	0.12
	1983	55	18.65	0.22
D10	1980	60	12.17	1.97
	1981	75	2.27	1.82
	1982	40	6.63	1.82
	1983	55	6.36	1.68
R236	1980	60	1.36	0.23
	1981	75	3.78	0.74
	1982	40	0.25	0.11
	1983	55	3.65	0.47
S246	1980	60	8.28	0.11
	1981	75	8.00	0.36
	1982	40	8.18	0.22
	1983	55	8.63	0.40

Table 6.27 Yearly means of scald and other selected variables from Massachusetts.

Variable	Year	N	Mean	SD	Variable	Year	N	Mean	SD
Scald	1987	60	21.81	19.98	D12	1987	60	45.25	4.08
	1988	77	14.42	18.02		1988	77	29.52	3.32
	1989	12	77.17	14.26		1989	12	31.50	2.61
	1990	24	75.13	20.95		1990	24	19.75	6.06
	1991	45	16.82	21.07		1991	45	26.00	6.96
	1992	15	77.87	28.68		1992	15	30.33	7.38
	1993	40	35.01	36.11		1993	40	25.25	9.17
DA	1987	60	60.08	4.56	R236	1987	60	5.80	0.25
	1988	77	57.23	3.79		1988	77	3.24	0.15
	1989	12	51.00	3.13		1989	12	5.41	0.04
	1990	24	49.25	7.69		1990	24	2.13	0.18
	1991	45	55.67	8.23		1991	45	5.11	0.46
	1992	15	44.33	8.51		1992	15	1.72	0.19
	1993	40	50.75	9.97		1993	40	4.11	0.68
ST	1987	60	2.28	0.58	S246	1987	60	0.46	0.01
	1988	77	2.71	1.03		1988	77	0.58	0.01
	1989	12	2.02	0.68		1989	12	0.37	0.01
	1990	24	2.86	1.78		1990	24	0.46	0.03
	1991	45	4.25	1.27		1991	45	0.42	0.02
	1992	15	2.33	0.68		1992	15	0.40	0.02
	1993	40	2.08	0.40		1993	40	0.41	0.06
AVG	1987	60	16.65	0.45					
	1988	77	19.02	0.56					
	1989	12	18.23	0.31					
	1990	24	19.20	0.54					
	1991	45	18.36	0.81					
	1992	15	18.05	0.77					
	1993	40	18.25	1.29					

Table 6.28 Testing a Logit equation designed to identify especially scald-susceptible lots of 'Delicious' apples using global harvest date (DA) as sole predictor of poststorage scald. Equation N=1000, with 721 observations at 0 and 279 observations at 1. Test N=186.

I (Index) = 1.64 - 0.0561DA[z]. t of DA coef=-10.76 NSI[y] = 0.138
If I ≥ 0, lot is predicted "Bad", otherwise, "OK".
Critical harvest date before which >60% of fruit will likely scald = 8 February/10 September (southern/northern hemisphere).

Test of equation:

ALL AREAS	# OK	# Bad
Predicted OK	130	38
Predicted Bad	8	10

Breakdown by area follows:

Area=1[x]	# OK	# Bad
Predicted OK	21	8
Predicted Bad	0	2

Area=9	# OK	# Bad
Predicted OK	41	5
Predicted Bad	4	0

Area=5	# OK	# Bad
Predicted OK	3	1
Predicted Bad	0	0

Area=10	# OK	# Bad
Predicted OK	6	2
Predicted Bad	0	0

Area=6	# OK	# Bad
Predicted OK	2	0
Predicted Bad	0	0

Area=11	# OK	# Bad
Predicted OK	39	18
Predicted Bad	0	0

Area=7	# OK	# Bad
Predicted OK	3	0
Predicted Bad	0	0

Area=12	# OK	# Bad
Predicted OK	3	1
Predicted Bad	0	1

Area=8	# OK	# Bad
Predicted OK	3	0
Predicted Bad	0	0

Area=13	# OK	# Bad
Predicted OK	9	3
Predicted Bad	4	7

[z] DA = 1 on 11 January (southern hemisphere); DA = 1 on 13 August (northern hemisphere).
[y] NSI = Normalized Success Index.
[x] Areas are as follow: 1=British Columbia, 5=Hawkes Bay, 6=Nelson, 7=Canterbury, 8=Otago, 9=Elgin, 10=High Noon, 11=Massachustts, 12=West Virginia, 13=Washington.

Table 6.29 Testing a Logit equation designed to identify especially scald-resistant lots of 'Delicious' apples using global harvest date (DA) as sole predictor of poststorage scald. Equation N=1000, with 525 observations at 0, 475 observations at 1. Test N=186.

I (Index) = $-3.72 + 0.0729DA^z$. t for DA coef=12.19 $NSI^y = 0.204$
If $I \geq 0$, lot is predicted "Good", otherwise, "Not good".
Critical harvest date after which fewer than 20% of fruit will likely scald is 2 March/2 October (southern/northern hemisphere).

Test of equation:

ALL AREAS	# Not good	# Good
Predicted not good	59	29
Predicted Good	30	68

Breakdown by area follows:

Area=1[x]	# Not good	# Good
Predicted Not good	13	1
Predicted Good	5	12

Area=9	# Not good	# Good
Predicted Not good	3	22
Predicted Good	6	19

Area=5	# Not good	# Good
Predicted Not good	1	0
Predicted Good	1	2

Area=10	# Not good	# Good
Predicted Not good	2	1
Predicted Good	4	1

Area=6	# Not good	# Good
Predicted Not good	0	0
Predicted Good	0	2

Area=11	# Not good	# Good
Predicted Not good	16	2
Predicted Good	13	26

Area=7	# Not good	# Good
Predicted Not good	0	0
Predicted Good	1	2

Area=12	# Not good	# Good
Predicted Not good	3	1
Predicted Good	0	1

Area=8	# Not good	# Good
Predicted Not good	0	0
Predicted Good	0	3

Area=13	# Not good	# Good
Predicted Not good	21	2
Predicted Good	0	0

[z] DA = 1 on 11 January (southern hemisphere); DA = 1 on 13 August (northern hemisphere).
[y] NSI = Normalized Success Index.
[x] Areas are as follow: 1=British Columbia, 5=Hawkes Bay, 6=Nelson, 7=Canterbury, 8=Otago, 9=Elgin, 10=High Noon, 11=Massachustts, 12=West Virginia, 13=Washington.

Table 6.30 Testing Logit equations designed to identify especially scald-susceptible lots of 'Delicious' apples using global harvest date (DA) as sole predictor of poststorage scald. A separate equation is made for each of 8 areas.

Area=1[y] N=182 Critical date[y] = 20 Sept NSI[x]=0.257	# OK	# Bad	Area=9 N=240 Critical date = 19 June[w] NSI=0.004	# OK	# Bad
Predicted OK	21	5	Predicted OK		
Predicted Bad	0	5	Predicted Bad		
Area=5 N=26 Critical date = 02 March NSI=0.831	# OK	# Bad	Area=10 N=64 Critical date = Nonsense[w]	# OK	# Bad
Predicted OK	3	0	Predicted OK		
Predicted Bad	0	1	Predicted Bad		
Area=6 N=25 Critical date = 21 Feb NSI=0.315	# OK	# Bad	Area=11 N=287 Critical date = 30 Sept NSI=0.493	# OK	# Bad
Predicted OK	2	0	Predicted OK	39	6
Predicted Bad	0	0	Predicted Bad	0	12
Area=7			Area=12 N=33 Critical date = 14 Sept NSI=0.279	# OK	# Bad
All observations = 0			Predicted OK	3	1
			Predicted Bad	0	1
Area=8			Area=13 N=122 Critical date = 10 Sept NSI=0.095	# OK	# Bad
All observations = 0			Predicted OK	9	3
			Predicted Bad	4	7

[z] Areas are as follow: 1=British Columbia, 5=Hawkes Bay, 6=Nelson, 7=Canterbury, 8=Otago, 9=Elgin, 10=High Noon, 11=Massachustts, 12=West Virginia, 13=Washington.
[y] Critical date is the harvest date before which over 60% of fruit will be expected to scald after storage.
[x] NSI = Normalized Success Index.
[w] The DA coefficient of this equation was positive (all other coefficients were negative), but not statistically different from zero, thus it was not tested.

Table 6.31 Testing Logit equations designed to identify especially scald-resistant lots of 'Delicious' apples using global harvest date (DA) as sole predictor of poststorage scald. A separate equation is made for each of 9 areas.

Area=1[z] N=182 Critical date[y] = 04 October NSI[x]=0.468	# Not good	# Good	Area=9 N=240 Critical date = nonsense[w] NSI=0.000	# Not good	# Good
Predicted Not good	15	1	Predicted Not good		
Predicted Good	3	12	Predicted Good		
Area=5 N=26 Critical date = 10 March NSI=0.476	# Not good	# Good	Area=10 N=64 Critical date = 6 April[w] NSI=0.024	# Not good	# Good
Predicted Not good	1	0	Predicted Not good		
Predicted Good	1	2	Predicted Good		
Area=6 N=25 Critical date = 04 March NSI=0.851	# Not good	# Good	Area=11 N=287 Critical date = 06 October NSI=0.331	# Not good	# Good
Predicted Not good	0	0	Predicted Not good	22	4
Predicted Good	0	2	Predicted Good	7	24
Area=7 N=6 Critical date = 07 March NSI=1.000	# Not good	# Good	Area=12 N=33 Critical date = 27 September NSI=0.235	# Not good	# Good
Predicted Not good	1	0	Predicted Not good	3	1
Predicted Good	0	2	Predicted Good	0	1
Area=8			Area=13 N=122 Critical date = 06 October NSI=0.142	# Not good	# Good
All observations = 1			Predicted Not good	21	2
			Predicted Good	0	0

[z] Areas are as follow: 1=British Columbia, 5=Hawkes Bay, 6=Nelson, 7=Canterbury, 8=Otago, 9=Elgin, 10=High Noon, 11=Massachustts, 12=West Virginia, 13=Washington.
[y] Critical date is the harvest date after which fewer than 20% of fruit are expected to scald after storage.
[x] NSI = Normalized Success Index.
[w] The DA coefficient of this equation was positive (all other coefficients were negative), but not statistically different from zero, thus it was not tested.

Table 6.32 Logit prediction equations to test global ability to identify especially scald-susceptible and especially scald-resistant 'Delicious' apples. Equations A and C use data from Elgin (Equation N=195; test N=35). Equations B and D use data from Massachusetts (Equation N=228; test N=45).

Equation	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	B_6 (t)	% of cases correctly placed	NSI[z]
A	-386	0.082 (0.27)	-3.7 (-1.35)	20 (1.06)	0.42 (0.36)	-3.2 (-0.50)	0.32 (0.04)	97	0.853
B	45	-0.18 (-2.01)	-0.44 (-1.29)	-1.5 (-1.78)	-0.28 (-1.87)	-0.67 (-3.38)	2.2 (0.35)	91	0.587
C	199	0.0097 (0.12)	2.6 (3.78)	-11 (-3.66)	-1.1 (-3.67)	-1.6 (-1.91)	1.8 (1.73)	94	0.737
D	-63	0.59 (4.82)	-0.79 (-3.21)	1.9 (2.14)	-0.051 (-0.32)	0.43 (1.58)	-6.5 (-0.92)	78	0.433

A. Elgin samples: Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

B. Massachusetts samples: Predict Bad if Index: $B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

C. Elgin samples: Predict Good[w] if Index: $B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

D. Massachusetts samples: Predict Good if Index: $B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

Test of Equation A	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted Bad (I<0)	30	1
Predicted Bad (I≥0)	0	4

Test of Equation B	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted Bad (I<0)	35	6
Predicted Bad (I≥0)	0	4

Test of Equation C	No. of cases actually:	
	Not good (0)	Good (1)
Not predicted good (I<0)	7	2
Predicted good (I≥0)	2	24

Test of Equation D	No. of cases actually:	
	Not good (0)	Good (1)
Not predicted good (I<0)	13	3
Predicted good (I≥0)	8	21

[z] NSI = Normalized Success Index.
[y] Bad refers to lots of fruit in which over 60% of fruit scalded.
[x] Abbreviations for variables are as used previously.
[w] Good refers to lots of fruit in which fewer than 20% of fruit scalded.

Table 6.33 Logit prediction equations to test global ability to identify especially scald-susceptible and especially scald-resistant 'Delicious' apples. Equations A and C use data from Elgin (Equation N=175, data from 1980-1982; test N=55, data from 1983). Equations B and D use data from Massachusetts (Equation N=233, data from 1987-1992; test N=40, data from 1993).

Equation	B_0	B_1	B_2	B_3	B_4	B_5	B_6	% of cases correctly placed	NSI[z]
A	-404	0.10 (0.36)	-3.8 (-1.60)	2.2 (1.31)	0.39 (0.39)	-3.6 (-0.63)	-0.63 (-0.08)	96	0.848
B	-30	-0.046 (-0.48)	-0.92 (-2.46)	-0.56 (-0.59)	-0.23 (-1.46)	-0.87 (-4.23)	-15 (-2.10)	91	0.601
C	428	-0.21 (-1.57)	4.3 (3.62)	-22 (-2.11)	-2.1 (-3.43)	-5.1 (-2.55)	3.6 (1.98)	93	0.755
D	-75	1.43 (4.38)	-0.71 (-2.90)	-1.6 (-0.67)	-1.4 (-2.50)	4.2 (3.65)	77 (2.42)	83	0.495

A. Elgin samples: Predict Bad[y] if Index: $B_0 + B_1DA^x + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

B. Massachusetts samples: Predict Bad if Index: $B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

C. Elgin samples: Predict Good[w] if Index: $B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

D. Massachusetts samples: Predict Good if Index: $B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246 \geq 0$

Test of Equation A	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted Bad (I<0)	55	0
Predicted Bad (I≥0)	0	0

Test of Equation B	No. of cases actually:	
	Not bad (0)	Bad (1)
Not predicted Bad (I<0)	15	0
Predicted Bad (I≥0)	13	12

Test of Equation C	No. of cases actually:	
	Not good (0)	Good (1)
Not predicted good (I<0)	0	0
Predicted good (I≥0)	3	52

Test of Equation D	No. of cases actually:	
	Not good (0)	Good (1)
Not predicted good (I<0)	20	20
Predicted good (I≥0)	0	0

[z] NSI = Normalized Success Index.
[y] Bad refers to lots of fruit in which over 60% of fruit scalded.
[x] Abbreviations for variables are as used previously.
[w] Good refers to lots of fruit in which fewer than 20% of fruit scalded.

CHAPTER VII

GLOBAL SCALD VARIATION IN 'GRANNY SMITH' APPLES

Introduction

This chapter describes global variation in scald in 'Granny Smith' in much the same way as the previous chapter described scald variation in 'Delicious' apples. Table 7.1 shows that there are fewer data available for 'Granny Smith' ("All" = 347) than there were for 'Delicious' ("All" = 1186), and that all of the data are from New Zealand and South Africa. Tables 7.2, 7.3, and 7.4 show the means and ranges of the data collected from the various areas. 'Granny Smith' are harvested later than 'Delicious', and therefore are subjected to more cool temperatures before harvest. Starch scores are cultivar-specific so comparisons among cultivars are not meaningful. Overall, the standard deviations of the variables were always at least 33% of the means, so if a variable influenced scald development, there is a reasonable chance that this may be shown using these data.

Developing Equations Relating Preharvest Variables to Scald

As was the case with the previously examined cultivars, the number of cases available for analysis varied according to which variables were to be used in equations. Harvest date and daily temperature minima and maxima were available for all 347 samples of 'Granny Smith'. Table 7.5 shows successes of equations relating scald development to harvest date. The highest R^2's were found for equations 1 and 2 (Auckland and Waikato, NZ), both of which included only one year of data and very few samples. The lowest R^2 was for Equation 8 (Elgin, SA). Harvest date appears to have been completely unrelated to scald development in Elgin, as was previously seen in the 'Delicious' data from Elgin. Chow's tests shown at the bottom of Table 7.5 show that separate equations are needed for the different areas. Although the equation for the combined New Zealand and South African data is not significantly different from the two separate equations, each of those two equations had been made from data of multiple areas which would have been better separated into individual equations for each area (first and second Chow's tests, Table 7.5), so that using the combined New Zealand/South Africa equation cannot be considered appropriate. The last Chow's test also showed equation differences among areas when all data were combined into one equation, as compared to each area having its own equation.

When average preharvest temperature (AVG) was added to the equations in Table 7.5, the equations in Table 7.6 resulted. The same cases were used in Table 7.6 as in Table 7.5. If corresponding equations are compared, the equation in Table 7.6 is different from and an improvement over the one in Table 7.5 for Hawkes Bay, Elgin, and High Noon. The equations for Waikato, Canterbury, and Otago have so few cases that the nonsignificant (P=0.05) changes in their error sums of squares should not be taken as strong evidence that preharvest temperature did not influence scald development on fruit from those areas. There were not enough samples from Auckland to compare equations from Tables 7.5 and 7.6. Thus, where substantial data existed, adding average temperature to harvest dates in equations raised the R^2s and reduced error. As in Table 7.5, separate equations were appropriate for separate areas, since Chow's tests were all significant.

Table 7.7 incorporates a factor for harvest starch score (ST) to the equations in Table 7.6. In some areas the number of cases was reduced, because harvest starch scores were not available. Where the same cases as in the previous tables were used (Canterbury, Otago, and Elgin), comparisons can be made. The Otago and Canterbury equations including ST were not different from the equations excluding ST, but the Elgin equations were different (P=0.01). When a factor for preharvest rainfall (R236) was added to the equations (Table 7.8), the Elgin equation again described a greater portion of the variability in scald development than had previously been described, and again an equation combining all data was different from the separate area-by-area equations.

Only Nelson, Canterbury, and Elgin data included both harvest starch scores and hourly temperature measurements. Preliminary analyses (not shown) showed that 10°C was the temperature at or below which cool weather effects were most associated with variation in scald development when variables used in Table 7.8 equations were also included in equations. Table 7.9 shows equations which include a variable for number of days with temperatures at or below 10°C between 01 January and harvest (D10). Variables for January rainfall (AR) and for preharvest temperatures at or exceeding 30°C in the week before harvest (D30W) were incorporated into Table 7.9. In addition, equations were developed using hourly rather than daily temperature information, and these equations are shown at the bottom of Table 7.9. Table 7.9 shows slightly higher R^2 values (and lower error sums of squares) for equations where daily temperature minima and maxima were used than for comparable equations where hourly temperatures were used (Equations D_D and E_D vs Equations D_H and E_H). This is consistent with results from the 'Cortland' and 'Delicious' studies. The signs of the coefficients are consistent throughout the table. In each of the two sections of the table, one equation incorporates all possible data. Subsequent equations break the data down into as many separate equations as possible, given the restrictions imposed by the individual data sets. The last equation in the top "daily temperatures" section was made to facilitate comparison with the "hourly temperatures" Equation E_H in the lower section of the table. The unexpected positive signs of the D10 and H10 coefficients are consistent with those of the 'Delicious' equations. The positive signs of the DA coefficients may be due to high percentage of data coming from Elgin, where scald development did not appear to be related to harvest date when the years were not separated. In the one equation (C) which did not include data from Elgin, the sign of the DA coefficient was not significant at P=0.05. Table 7.10, a table of correlation matrices, shows that D10, H10, and DA all were correlated negatively to scald (P=0.05), and that many of the "independent" variables were correlated to one another.

Developing Equations to Predict Scald Susceptibility

As with the 'Cortland' and 'Delicious' data, an objective of this study was to identify at harvest lots of fruit that are especially scald-susceptible and especially scald-resistant. Variables were used in equations according to their availability and whether or not variation existed in them.

New Zealand

In the New Zealand areas sampled, no single area had enough lots of fruit to use alone for scald prediction, so all New Zealand fruit were placed in one group for predictions of scald-susceptibility. Two sets of equations were generated, one using only harvest date to predict scald-susceptibility, and the other using starch score, average preharvest temperature, number of preharvest days at or below 10°C, number of preharvest days at or above 30°C, average daily rainfall from 22 January to harvest, and average daily rainfall during January, as well as harvest date, to predict extent of scald development. To develop the equations, 85% of the available cases were selected at random, and Logit equations were generated (separately) identifying scald-susceptible and scald-resistant lots of fruit. As with the 'Cortland' and 'Delicious', indices were based on whether or not the lot had > 60% scald (yes=1; n=0) for equations identifying scald-susceptible fruit, or whether or not the lot had < 20% scald (yes=1; no=0) for equations identifying scald-resistant fruit. The remaining 15% of lots were used as the test lots for the predictions. Table 7.11 shows the equations as well as results of testing the equations. The Normalized Success Indices (NSI) show that Equations B and D, with more independent variables than Equations A and C, assigned lots to the correct category more successfully. In testing Equations A and B, identifying especially scald-susceptible fruit, Equation B placed all 12 test samples correctly, while Equation A misplaced 1 of the 3 "Bad" samples. Because so few samples were "Bad", it is difficult to evaluate these results. Results of testing Equations C and D were not promising. Equation C correctly placed 8 of the 10 "Good" samples, which could be useful, but also placed 4 of the 7 "Not good" samples in the "Good" category, which would be a problem if the equation were used commercially. Equation D correctly identified all 8 "Good" samples, but incorrectly placed 3 of 4 "Not good" samples, again not an acceptable situation commercially. In addition, since the test data were a random subsample of the data used to generate the equations, it may be expected that the test results would have been poorer if test data had been from a year/area combination which had not been used to generate the equations. Results likely would be better if predictions could be made separately for each area. This could be done with the South Africa data.

<u>South Africa</u>

Since five years of data were available from Elgin, SA, the initial decision was made to pool the data from the first four years to generate Logit equations identifying especially scald-susceptible and especially scald-resistant lots of fruit, and then to test the equations on the fifth year of data. This proved impossible, as shown in Table 7.12, which breaks down by year the means of and the variation in variables. Only in 1991 were there any "Bad" lots of fruit. Thus, using only the 1980-1983 data no equation relating to "Bad" fruit could be made. Of 125 sample lots from 1980-1983 all but 4 were in the "Good" category. There were not enough "Not good" samples to generate a Logit equation in which one could have confidence. In 1991 a very different pattern of scald existed, and all but 1 of 35 lots of fruit were "Bad"; no lots were "Good".

Looking at Table 7.12 to see if there were eye-catching differences between 1991 and the other years in variables relating to scald, some observations could be made. In 1991 there was less preharvest rain and higher preharvest light intensity than in the other years. Average harvest date (10 April) was the average of the other years. Harvest starch score for 1991, averaging 2.2, was relatively low, but was the same as in 1982, a year in which all fruit were classified "Good". Average preharvest temperature (AVG) did not vary much from year to year. The number of preharvest days at or below 10°C (D10) was slightly above the average in 1991, but the number of days at or above 30°C (D30W) in the week before harvest was also above average.

Since it was not possible to use four years of data to predict scald severity in the fifth year, a randomly selected 85% of cases was used to generate Logit equations, as had been done previously, and equations were tested on the remaining 15% of cases. Table 7.13 shows the equations, as well as results of testing them. Variables used were the same as those used for the New Zealand equations, except that January rainfall (AR) was omitted from all equations, and D30W was omitted from the "Bad" equations, because the small variations within these variables and within the "Bad" and "Good" categories made their use in the Logit equations impossible. Comparisons of the NSI of the equations and of the tests of the equations showed that using harvest date alone (Equations A and D) was not at all effective in identifying either "Bad" or "Good" lots of fruit. Using all variables in equations (C and F) made identification of lots quite successful. It must be noted again, however, that the tests were made on a subsample of the same sample from which another subsample had been used to generate the equations. Had it been possible to make equations from 4 years of data and test those equations with the fifth year of data, results might have been different. In any event, the "Bad" Equation C correctly placed all 26 test samples (6 "Bad" samples from 1991; 20

"Not Bad" samples from other years), and the "Good" Equation F correctly placed 25 of 26 samples, misidentifying only 1 "Good" sample, and never placing a lot in the category which would have led to undertreatment.

Examination of the High Noon data (Table 7.14) showed that again there were year-to-year differences in scald development. There was significantly more scald in 1987 than in 1986, with intermediate scald in 1988. Only in 1986 were there any "Good" fruit. In 1987 all fruit were "Bad". Also, there were never any days at or above 30°C in the week before harvest in 1986. Daily rainfall for the three weeks preceding harvest varied from 0.21 to 0.26 mm in 1987, from 0.47 to 0.99 mm in 1988, and from 1.06 to 1.46 mm in 1986. Thus, it would be difficult to make equations relating scald severity to preharvest factors when so many values of the factors were so year-specific. It therefore was decided to combine the Elgin and High Noon data, create Logit equations using a randomly selected 85% of the samples, and test these equations with the remaining 15% of samples. Table 7.15 shows these combined equations, as well as the tests of these equations. The tests show Elgin and High Noon samples separately, so if an equation worked differently for one location, this could be seen. Equations A and C, which used only harvest date as a predictor of scald severity, did not work at all well. This is hardly surprising as harvest date did not correlate well with scald development in South Africa, except for within a given year. Equation A put 33 of 35 test samples in the "Not Bad" category, though only 13 of the 35 actually were "Bad", and Equation C placed 7 of the 20 "Good" samples from Elgin in the "Not Good" category. Equations A and C, with NSI's of 0.03 and 0.04, respectively, and especially Equation A, with its poor test results cannot be considered at all useful. Using more variables improved the equations substantially. The NSI of 0.735 indicated that Equation B separated especially scald-susceptible fruit from those less scald-susceptible much of the time. When tested, Equation B misplaced 2 of 6 "Bad" samples from Elgin, and misplaced 2 of 7 "Bad" samples from High Noon. Not surprisingly, the Elgin Equation C in Table 7.13 did better for Elgin alone (NSI=0.785 and all 26 test lots were corectly place). Table 7.15, Equation D with a NSI of 0.591 did not do as well as Equation B, but when tested, did not place any "Not Good" sample in the "Good" category. Fifteen of 21 "Good" samples were correctly identified and could have been spared excessive antiscald treatment, while no more scald-susceptible lots of fruit would have been undertreated. Again, while the Elgin Equation F from Table 7.13 fit the Elgin test data better than the combined Equation D in Table 7.15, the combined equation did very well and can be considered a success.

Table 7.1 Data available for scald analyses of 'Granny Smith' apples.

Area	Cases available for Scald, DA[z], Dx[y], AVG[x]			Cases available for ST[w]			Cases available for Hx[v]		
	Years		N	Years		N	Years		N
All			347			252			292
Auckland, NZ	1	1991	6			0	1	1991	6
Waikato, NZ	1	1990	8	1	1990	7			0
Hawkes Bay, NZ	5	1987-91	45	4	1987-90	37	1	1991	8
Nelson, NZ	4	1988-91	33	3	1988-90	25	4	1988-91	33
Canterbury, NZ	2	1989-90	13	2	1989-90	13	2	1989-90	13
Otago, NZ	2	1989-90	10	2	1989-90	10			0
Elgin, SA	5	1980-83, 1991	160	5	1980-83, 1991	160	5	1980-83, 1991	160
High Noon, SA	3	1986-88	72			0	3	1986-88	72

[z] DA = Harvest date as number of days after 06 March.

[y] Dx = Number of preharvest days in which temperatures fell to or below x; x = 6, 8, 10, or 12.
Number of preharvest days in which temperatures reached or exceeded x; x = 30.

[x] AVG = Average of daily temperature minima and maxima from 01 January to harvest.

[w] ST = Harvest starch score.

[v] Hx = Number of preharvest hours in which temperatures fell to or below x; x = 6, 8, 10, or 12.
Number of preharvest hours in which temperatures reached or exceeded x; x = 30.

Table 7.2 Descriptions of variables for which daily preharvest temperature measurements were available for the 'Granny Smith' apple scald study.

Area	Variable	N	Mean	SD	Min	Max
All	Percent Scald	347	35	41	0	100
Auckland, NZ		6	85	30	25	100
Waikato, NZ		8	79	30	25	99
Hawkes Bay, NZ		45	25	35	0	99
Nelson, NZ		33	38	34	0	99
Canterbury, NZ		13	7	17	0	58
Otago, NZ		10	4	7	0	23
Elgin, SA		160	23	38	0	100
High Noon, SA		72	68	35	0	100
All	Harvest Date	347	11 April	16	07 March	26 May
Auckland, NZ		6	01 April	14	14 March	20 April
Waikato, NZ		8	13 April	18	18 March	08 May
Hawkes Bay, NZ		45	17 April	20	07 March	26 May
Nelson, NZ		33	13 April	18	12 March	19 May
Canterbury, NZ		13	15 April	15	23 March	11 May
Otago, NZ		10	05 April	12	21 March	26 April
Elgin, SA		160	10 April	16	14 March	08 May
High Noon, SA		72	09 April	10	24 March	28 April
All	Harvest Starch Score	252	2.9	1.4	0.3	6.0
Waikato, NZ		7	2.5	1.4	1.2	4.4
Hawkes Bay, NZ		37	3.5	1.4	1.1	6.0
Nelson, NZ		25	2.6	1.5	0.3	5.4
Canterbury, NZ		13	2.8	1.3	0.8	4.8
Otago, NZ		10	1.9	1.1	0.3	3.9
Elgin, SA		160	2.9	1.4	1.0	5.8
All	R236[z]	324	1.67	1.10	0.21	4.87
Hawkes Bay, NZ		36	2.43	1.46	0.44	4.87
Nelson, NZ		33	2.27	0.99	0.73	4.72
Canterbury, NZ		13	1.15	0.08	1.05	1.30
Otago, NZ		10	1.08	0.37	0.60	1.54
Elgin, SA		160	1.85	1.02	0.32	3.68
High Noon, SA		72	0.79	0.48	0.21	1.46

[z] R236 = Average daily rainfall in mm from Day 236 (22 January) to harvest.

Table 7.3 Daily preharvest temperature measurements available for the 'Granny Smith' apple scald study.

Area	Variable	N	Mean	SD	Min	Max
All	D6[z]	347	4	6	0	33
Auckland, NZ		6	0	0	0	1
Waikato, NZ		8	4	3	0	8
Hawkes Bay, NZ		45	10	8	0	32
Nelson, NZ		33	6	8	0	32
Canterbury, NZ		13	10	6	2	20
Otago, NZ		10	17	8	6	33
Elgin, SA		160	1	2	0	7
High Noon, SA		72	2	2	0	5
All	D8[z]	347	10	9	0	55
Auckland, NZ		6	5	2	3	9
Waikato, NZ		8	10	5	3	16
Hawkes Bay, NZ		45	18	12	2	47
Nelson, NZ		33	14	14	0	53
Canterbury, NZ		13	18	8	6	32
Otago, NZ		10	31	13	12	55
Elgin, SA		160	7	5	0	21
High Noon, SA		72	8	5	3	17
All	D10[z]	347	23	12	0	72
Auckland, NZ		6	16	6	11	25
Waikato, NZ		8	15	8	5	26
Hawkes Bay, NZ		45	30	15	5	59
Nelson, NZ		33	25	17	0	66
Canterbury, NZ		13	31	12	13	51
Otago, NZ		10	52	12	36	72
Elgin, SA		160	19	9	3	43
High Noon, SA		72	23	8	10	40
All	D12[z]	347	45	15	6	95
Auckland, NZ		6	28	8	18	40
Waikato, NZ		8	34	11	19	48
Hawkes Bay, NZ		45	46	21	12	95
Nelson, NZ		33	42	19	6	80
Canterbury, NZ		13	49	14	27	72
Otago, NZ		10	68	13	49	93
Elgin, SA		160	45	12	19	67
High Noon, SA		72	46	11	29	62
All	D30W[y]	347	0.26	0.69	0	3
Auckland, NZ		6	0	0	0	0
Waikato, NZ		8	0	0	0	0
Hawkes Bay, NZ		45	0.02	0.15	0	1
Nelson, NZ		33	0	0	0	0
Canterbury, NZ		13	0	0	0	0
Otago, NZ		10	0	0	0	0
Elgin, SA		160	0.62	0.90	0	3
High Noon, SA		72	0.25	0.44	0	1

[z] Dx = Number of preharvest days in which the recorded temperature was less than or equal to x°C; x = 6, 8, 10, or 12.
[y] D30W = Number of preharvest days in which the temperature reached or exceeded 30°C during the week immediately preceding harvest.

Table 7.4 Hourly preharvest temperature measurements available for the 'Granny Smith' apple scald study.

Area	Variable	N	Mean	SD	Min	Max
All	H6[z]	292	11	23	0	166
Auckland, NZ		6	1	2	0	6
Hawkes Bay, NZ		8	46	42	9	106
Nelson, NZ		33	31	44	0	166
Canterbury, NZ		13	52	36	11	123
Elgin, SA		160	5	9	0	37
High Noon, SA		72	5	7	0	21
All	H8[z]	292	40	48	0	365
Auckland, NZ		6	14	8	8	29
Hawkes Bay, NZ		8	82	62	22	166
Nelson, NZ		33	80	97	0	365
Canterbury, NZ		13	109	66	26	231
Elgin, SA		160	28	26	0	116
High Noon, SA		72	32	22	10	78
All	H10[z]	292	114	85	0	620
Auckland, NZ		6	77	27	53	122
Hawkes Bay, NZ		8	175	111	53	330
Nelson, NZ		33	171	162	0	620
Canterbury, NZ		13	223	123	62	460
Elgin, SA		160	91	51	11	255
High Noon, SA		72	115	48	47	210
All	H12[z]	292	272	132	22	907
Auckland, NZ		6	171	57	113	259
Hawkes Bay, NZ		8	317	172	118	566
Nelson, NZ		33	309	223	22	907
Canterbury, NZ		13	471	199	201	836
Elgin, SA		160	240	90	67	445
High Noon, SA		72	290	96	135	469
All	H30W[y]	292	1.1	2.6	0	14
Auckland, NZ		6	0	0	0	0
Hawkes Bay, NZ		8	0	0	0	0
Nelson, NZ		33	0	0	0	0
Canterbury, NZ		13	0	0	0	0
Elgin, SA		160	1.8	3.3	0	14
High Noon, SA		72	0.3	0.6	0	2

[z] Hx = Number of preharvest hours in which the recorded temperature was less than or equal to x°C; x = 6, 8, 10, or 12.
[y] H30W = Number of preharvest hours in which the temperature reached or exceeded 30°C during the week immediately preceding harvest.

Table 7.5 Equations relating harvest date to poststorage scald development on 'Granny Smith' apples. Equations are of the form: Percent scald = $B_0 + B_1DA^z$.

Equation Number	Areas included in equation	N	R^2	Error SS	Chow's F
1	Auckland, NZ	6	0.59	1802	
2	Waikato, NZ	8	0.68	2032	
3	Hawkes Bay, NZ	45	0.52	26329	
4	Nelson, NZ	33	0.37	22856	
5	Canterbury, NZ	13	0.36	2313	
6	Otago, NZ	10	0.19	398	
7	All New Zealand	115	0.34	106020	
8	Elgin, SA	160	0.01	233210	
9	High Noon, SA	72	0.44	47424	
10	All South Africa	232	0.04	406840	
11	All samples	347	0.11	521070	
	Chow's tests:	Equations:			
	Among NZ areas	1-6 vs 7			9.29**y
	Among SA areas	8,9 vs 10			51.27**
	NZ vs SA	7,10 vs 11			2.75ns
	Among all areas	1-6,8,9 vs 11			12.98**

z DA = Harvest date as number of days after 06 March.
y ns = not significant at P=0.05; ** = significant at P=0.01.

Table 7.6 Equations relating harvest date and average preharvest temperature to poststorage scald development on 'Granny Smith' apples. Equations are of the form: Percent scald = $B_0 + B_1DA^z + B_2AVG^y$.

Equation Number	Areas included in equation	N	R^2	Error SS	Chow's F
1	Auckland, NZ	6	0.90	434	
2	Waikato, NZ	8	0.86	875	
3	Hawkes Bay, NZ	45	0.61	21190	
4	Nelson, NZ	33	0.38	22497	
5	Canterbury, NZ	13	0.44	2033	
6	Otago, NZ	10	0.55	220	
7	All New Zealand	115	0.45	87299	
8	Elgin, SA	160	0.05	222550	
9	High Noon, SA	72	0.51	41780	
10	All South Africa	232	0.07	393030	
11	All samples	347	0.15	494780	
	Chow's tests:	Equations:			
	Among NZ areas	1-6 vs 7			5.48**x
	Among SA areas	8,9 vs 10			36.68**
	NZ vs SA	7,10 vs 11			3.42*
	Among all areas	1-6,8,9 vs 11			9.04**

z DA = Harvest date as number of days after 06 March.
y AVG = Average of daily temperature minima and maxima from 01 January to harvest.
x ns = not significant at P=0.05; * = significant at P=0.05; ** = significant at P=0.01.

Table 7.7 Equations relating harvest date, average preharvest temperature, and harvest starch score to poststorage scald development on 'Granny Smith' apples. Equations are of the form: Percent scald = $B_0 + B_1DA^z + B_3AVG^y + B_2ST^x$.

Equation Number	Areas included in equation	N	R^2	Error SS	Chow's F
1	Waikato, NZ	7	0.90	451	
2	Hawkes Bay, NZ	37	0.76	12436	
3	Nelson, NZ	25	0.60	10996	
4	Canterbury, NZ	13	0.51	1751	
5	Otago, NZ	10	0.56	220	
6	All New Zealand	92	0.49	62552	
7	Elgin, SA	160	0.39	143850	
8	All samples	252	0.28	259120	
	Chow's tests:	Equations:			
	Among NZ areas	1-5 vs 6			6.39**[w]
	NZ vs SA	6,7 vs 8			31.16**
	Among all areas	1-5,7 vs 8			12.01**

[z] DA = Harvest date as number of days after 06 March.
[y] AVG = Average of daily temperature minima and maxima from 01 January to harvest.
[x] ST = Harvest starch score.
[w] ns = not significant at P=0.05; ** = significant at P=0.01.

Table 7.8 Equations relating harvest date and starch score, and preharvest average temperature and rainfall to poststorage scald development on 'Granny Smith' apples. Equations are of the form: Percent scald = $B_0 + B_1DA^z + B_2ST + B_3AVG + B_4R236$.

Equation Number	Areas included in equation	N	R^2	Error SS	Chow's F
1	Hawkes Bay, NZ	36	0.77	11261	
2	Nelson, NZ	25	0.61	10759	
3	Canterbury, NZ	13	0.52	1745	
4	Otago, NZ	10	0.61	192	
5	All New Zealand	84	0.47	50150	
6	Elgin, SA	160	0.46	127550	
7	All samples	244	0.28	235090	
	Chow's tests:	Equations:			
	Among NZ areas	1-4 vs 5			4.66^{**v}
	NZ vs SA	5,6 vs 7			15.11^{**}
	Among all areas	1-4,6 vs 7			6.04^{**}

[z] DA = Harvest date as number of days after 06 March.
[y] AVG = Average of daily temperature minima and maxima from 01 January to harvest.
[x] ST = Harvest starch score.
[w] R236 = Average daily rainfall in mm from Day 236 (22 January) to harvest.
[v] ns = not significant at P=0.05; ** = significant at P=0.01.

Table 7.9 OLS equations relating poststorage scald development on 'Granny Smith' apples to harvest date and starch score and to preharvest temperature and rainfall. Equations are of the form: Percent scald = $B_0 + B_1DA^z + B_2ST^y + B_3AVG^x + B_4D10^w + B_5D30W^v + B_6R236^u + B_7AR^t$, or Percent scald = $B_0 + B_1DA^z + B_2ST^y + B_3AVG^x + B_4H10^s + B_5H30W^r + B_6R236^u + B_7AR^t$.

Equation	Areas included in equation	N		R^2	Error SS	Significance at P=0.05 of B_x of:						
		By area	Total			DA	ST	AVG	D10	D30W	R236	AR
A	Hawkes Bay Nelson Canterbury Otago Elgin	36 25 13 10 160	244	0.38	204290	+	-	+	ns	+	-	-
B	Hawkes Bay Elgin	36 160	196	0.53	133590	+	-	+	+	+	-	-
C	Hawkes Bay	36		0.82	9162	ns	-	ns	ns	+	ns	ns
D_D	Elgin	160		0.59	95187	+	-	+	+	+	-	ns
E_D	Nelson Canterbury Elgin	25 13 160	198	0.46	146630	+	-	+	+	+	-	-

Equation	Areas included in equation	N		R^2	Error SS	Significance at P=0.05 of B_x of:						
		By area	Total			DA	ST	AVG	H10	H30W	R236	AR
D_H	Elgin	160		0.56	103000	+	-	+	ns	+	-	ns
E_H	Nelson Canterbury Elgin	25 13 160	198	0.44	152020	+	-	+	+	+	-	-

[z] DA = Harvest date as days after 06 March.
[y] ST = Harvest starch score.
[x] AVG = Average of daily temperature maxima and minima from 01 January to harvest.
[w] D10 = Number of days with temperature at or below 10°C between 01 January and harvest.
[v] D30W = Number of days with temperature at or above 30°C during the week before harvest.
[u] R236 = Average daily rainfall in mm from Day 236 (22 January) to harvest.
[t] AR = Average daily rainfall in mm during January.
[s] H10 = Number of hours with temperature at or below 10°C between 01 January and harvest.
[r] H30W = Number of hours with temperature at or above 30°C during the week before harvest.

Table 7.10 Correlation matrices of variables used in constructing equations in Table 7.9.

Scald	1.00			N = 244. These are correlation coefficients for data used in top equations in Table 7.9.				
DA[z]	-0.25	1.00						
ST	-0.39	+0.89	1.00					
AVG	+0.25	-0.46	-0.32	1.00				
D10	-0.19	+0.75	+0.63	-0.71	1.00			
D30W	+0.18	-0.10	+0.02	+0.27	-0.12	1.00		
R236	-0.35	+0.07	+0.25	-0.07	+0.02	+0.03	1.00	
AR	-0.32	-0.01	+0.07	+0.05	-0.06	+0.03	+0.29	1.00
	Scald	DA	ST	AVG	D10	D30W	R236	AR

Scald	1.00			N = 198. These are correlation coefficients for data used in equations at bottom of Table 7.9.				
DA	-0.15	1.00						
ST	-0.36	+0.87	1.00					
AVG	+0.16	-0.43	-0.30	1.00				
H10	-0.11	+0.73	+0.62	-0.79	1.00			
H30W	+0.29	-0.04	-0.01	+0.20	-0.10	1.00		
R236	-0.45	-0.01	+0.26	-0.08	+0.08	-0.06	1.00	
AR	-0.34	+0.04	+0.14	+0.05	-0.10	+0.05	+0.46	1.00
	Scald	DA	ST	AVG	H10	H30W	R236	AR

[z] All abbreviations are as in Table 7.9.

Table 7.11 Logit equations to identify especially scald-susceptible and especially scald-resistant lots of New Zealand-grown 'Granny Smith' apples using preharvest factors. Equations A and C: N=98; Equations B and D: N=72.

$I=B_xX$	B_x for factor listed below:						NSI
Equation	Const (B_0)	DA (t)	ST (t)	AVG (t)	D10 (t)	R236 (t)	
A	2.3	-0.10 (-4.36)					0.305
B	-27	-0.095 (-1.00)	-0.082 (-0.08)	1.7 (2.25)	-0.026 (-0.48)	-0.076 (-0.22)	0.624
C	-2.0	0.061 (4.00)					0.199
D	2.9	0.11 (2.00)	-0.75 (-1.35)	-0.28 (-0.89)	0.036 (1.23)	-0.20 (-0.81)	0.374

A $I_b{}^z = B_0 + B_1DA$
B $I_b = B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236$
C $I_g{}^y = B_0 + B_1DA$
D $I_g = B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236$

Tests of Equations A through D:

Test of Equation A N=17	Samples not actually "Bad"(0)	Samples actually "Bad"(1)
Samples not predicted "Bad"(I<0)	14	1
Samples predicted "Bad"(I≥0)	0	2

Test of Equation B N=12	Samples not actually "Bad"(0)	Samples actually "Bad"(1)
Samples not predicted "Bad"(I<0)	12	0
Samples predicted "Bad"(I≥0)	0	0

Test of Equation C N=17	Samples not actually "Good"	Samples actually "Good"
Samples not predicted "Good"(I<0)	3	2
Samples predicted "Good"(I≥0)	4	8

Test of Equation D N=12	Samples not actually "Good"	Samples actually "Good"
Samples not predicted "Good"(I<0)	1	0
Samples predicted "Good"(I≥0)	3	8

[z] If $I_b \geq 0$, then > 60% of fruit in the lot are predicted to scald. These samples are considered "Bad". In Equation A 27/98 lots are "Bad". In Equation B 19/72 lots are "Bad".
[y] If $I_g \geq 0$, then < 20% of fruit in the lot are predicted to scald. These samples are considered "Good". In Equation C 54/98 lots are "Good". In Equation D 40/72 lots are "Good".

Table 7.12 Means of percent scald and related variables, by year, for Elgin-grown 'Granny Smith' apples.

Variable[z]	Year	N	Mean	SD	Minimum	Maximum
% Scald	All	160	23	38	0	100
	1980	15	5	7	0	20
	1981	40	4	8	0	32
	1982	30	1	2	0	8
	1983	40	2	3	0	12
	1991	35	94	11	47	100
"Bad"	All	160	0.21	0.41	0	1
	1980	15	0.00	0.00	0	0
	1981	40	0.00	0.00	0	0
	1982	30	0.00	0.00	0	0
	1983	40	0.00	0.00	0	0
	1991	35	0.97	0.17	0	1
"Good"	All	160	0.76	0.43	0	1
	1980	15	0.93	0.26	0	1
	1981	40	0.93	0.27	0	1
	1982	30	1.00	0.00	1	1
	1983	40	1.00	0.00	1	1
	1991	35	0.00	0.00	0	0
DA	All	160	35	16	8	63
	1980	15	46	15	28	63
	1981	40	37	17	10	62
	1982	30	32	15	11	52
	1983	40	32	16	8	54
	1991	35	35	14	14	56
ST	All	160	2.9	1.4	1.0	5.8
	1980	15	3.7	1.7	1.8	5.8
	1981	40	3.3	1.4	1.4	5.4
	1982	30	2.2	0.9	1.1	3.4
	1983	40	3.4	1.4	1.5	5.5
	1991	35	2.2	0.9	1.0	3.8
AVG	All	160	18.53	0.32	17.83	19.27
	1980	15	18.63	0.49	18.13	19.27
	1981	40	18.48	0.39	17.84	19.13
	1982	30	18.30	0.33	17.83	18.67
	1983	40	18.63	0.13	18.41	18.76
	1991	35	18.60	0.12	18.38	18.78
D10	All	160	19	9	3	43
	1980	15	30	11	17	43
	1981	40	20	10	3	34
	1982	30	14	5	9	21
	1983	40	17	5	10	26
	1991	35	22	6	14	32
D30W	All	160	0.63	0.90	0.00	3.00
	1980	15	0.33	0.49	0.00	1.00
	1981	40	0.63	1.00	0.00	3.00
	1982	30	0.00	0.00	0.00	0.00
	1983	40	0.88	0.79	0.00	2.00
	1991	35	1.00	1.08	0.00	3.00

Table 7.12 continued

Variable[z]	Year	N	Mean	SD	Minimum	Maximum
R236	All	160	1.85	1.02	0.32	3.68
	1980	15	1.28	0.26	0.93	1.54
	1981	40	2.83	0.21	2.49	3.08
	1982	30	0.94	0.51	0.32	1.58
	1983	40	2.76	0.52	2.15	3.68
	1991	35	0.72	0.16	0.51	0.93
S246	All	160	8.22	1.97	7.23	19.01
	1980	15	7.81	0.35	7.48	8.27
	1981	40	7.72	0.31	7.23	8.11
	1982	30	7.67	0.37	7.25	8.15
	1983	40	7.94	0.26	7.52	8.32
	1991	35	9.74	3.84	8.06	19.01
AR	All	160	1.84	1.65	0.70	4.68
	1980	15	1.25	0.00	1.25	1.25
	1981	40	4.68	0.00	4.68	4.68
	1982	30	1.11	0.00	1.11	1.11
	1983	40	0.78	0.00	0.78	0.78
	1991	35	0.70	0.00	0.70	0.70

[z] Variable abbreviations are as in Table 7.9 and Table 7.11.

Table 7.13 Logit equations to identify especially scald-susceptible and especially scald-resistant lots of Elgin, SA-grown 'Granny Smith' apples using preharvest factors. Equation N=134. Test N=26.

$I=B_xX$	B_x for factor listed below:							
Equation	Const	DA (t)	ST (t)	AVG (t)	D10 (t)	D30W (t)	R236 (t)	S246 (t)	NSI
A	-0.88	-0.013 (-0.98)							0.006
B	7.1	0.20 (1.56)	-5.4 (-3.00)	-0.41 (-0.24)	0.54 (3.10)		-5.2 (-2.19)		0.711
C	87	3.2 (1.57)	-42 (-1.65)	-2.8 (-1.05)	2.7 (1.72)		-58 (-1.62)	-5.1 (-1.53)	0.785
D	0.42	0.020 (1.58)							0.018
E	47	-0.17 (-1.95)	4.3 (2.89)	-2.5 (-1.47)	-0.27 (-2.49)	-0.75 (-2.05)	0.056 (0.11)		0.602
F	43	-0.39 (-2.13)	5.1 (2.22)	2.7 (1.02)	0.11 (0.50)	-0.42 (-0.76)	-0.40 (-0.67)	-12 (-2.04)	0.694

A $I_b^z = B_0 + B_1DA$
B $I_b = B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236$
C $I_b = B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5R236 + B_6S246$
D $I_g^y = B_0 + B_1DA$
E $I_g = B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5D30W + B_6R236$
F $I_g = B_0 + B_1DA + B_2ST + B_3AVG + B_4D10 + B_5D30W + B_6R236 + B_7S246$

Test of Equation A	Samples not actually "Bad"(0)	Samples actually "Bad"(1)	Test of Equation D	Samples not actually "Good"(0)	Samples actually "Good"(1)
Samples not predicted "Bad"(I<0)	20	6	Samples not predicted "Good"(I<0)	0	0
Samples predicted "Bad"(I≥0)	0	0	Samples predicted "Good"(I≥0)	6	20
Test of Equation B	**Samples not actually "Bad"(0)**	**Samples actually "Bad"(1)**	**Test of Equation E**	**Samples not actually "Good"(0)**	**Samples actually "Good"(1)**
Samples not predicted "Bad"(I<0)	20	0	Samples not predicted "Good"(I<0)	6	1
Samples predicted "Bad"(I≥0)	0	6	Samples predicted "Good"(I≥0)	0	19
Test of Equation C	**Samples not actually "Bad"**	**Samples actually "Bad"**	**Test of Equation F**	**Samples not actually "Good"**	**Samples actually "Good"**
Samples not predicted "Good"(I<0)	20	0	Samples not predicted "Good"(I<0)	6	1
Samples predicted "Bad"(I≥0)	0	6	Samples predicted "Good"(I≥0)	0	19

[z] If $I_b \geq 0$, then > 60% of fruit in the lot are predicted to scald and the lot is considered "Bad". In Equations A-C 28/134 lots are "Bad".
[y] If $I_g \geq 0$, then < 20% of fruit in the lot are predicted to scald and the lot is considered "Good". In Equations D-F 101/134 lots are "Good".

Table 7.14 Means of percent scald and various related variables, by year, for High Noon grown 'Granny Smith' apples.

Variable^z	Year	N	Mean	SD	Minimum	Maximum
%Scald	All	72	68	35	0	100
	1986	24	37	41	0	100
	1987	24	92	8	70	100
	1988	24	77	17	37	99
"Bad"	All	72	0.69	0.46	0	1
	1986	24	0.25	0.44	0	1
	1987	24	1.00	0.00	1	1
	1988	24	0.83	0.38	0	1
"Good"	All	72	0.17	0.38	0	1
	1986	24	0.50	0.51	0	1
	1987	24	0.00	0.00	0	0
	1988	24	0.00	0.00	0	0
DA	All	72	34	10	18	53
	1986	24	36	13	19	53
	1987	24	29	8	18	39
	1988	24	36	8	25	47
AVG	All	72	18.59	0.82	17.67	20.05
	1986	24	18.07	0.39	17.67	18.66
	1987	24	18.05	0.10	17.9	18.16
	1988	24	19.67	0.31	19.26	20.05
D10	All	72	23	8	10	40
	1986	24	30	9	17	40
	1987	24	22	3	20	28
	1988	24	15	4	10	20
D30W	All	72	0.25	0.4	0	1
	1986	24	0	0	0	0
	1987	24	0.25	0.4	0	1
	1988	24	0.5	0.5	0	1
R236	All	72	0.79	0.48	0.21	1.46
	1986	24	1.33	0.16	1.06	1.46
	1987	24	0.23	0.02	0.21	0.26
	1988	24	0.81	0.20	0.47	0.99
AR	All	72	0.13	0.08	0.03	0.23
	1986	24	0.13	0.00	0.13	0.13
	1987	24	0.23	0.00	0.23	0.23
	1988	24	0.03	0.00	0.03	0.03

^{z} Variable abbreviations are as in Table 7.9 and Table 7.11.

Table 7.15 Logit equations to identify especially scald-susceptible and especially scald-resistant lots of SA-grown 'Granny Smith' apples using preharvest factors. Equation N=197. Test N=35.

$I=B_xX$	B_x for factor listed below:							
Equation	Const	DA (t)	AVG (t)	D10 (t)	D30W (t)	R236 (t)	AR (t)	NSI
A	0.34	-0.026 (-2.74)						0.030
B	-5.7	0.018 (0.32)	0.62 (0.45)	0.067 (0.49)	1.4 (1.89)	-6.6 (-3.66)	-4.0 (-3.29)	0.735
C	-0.80	0.031 (2.93)						0.044
D	54	0.082 (2.46)	-3.0 (-3.86)	-0.17 (-2.78)	-0.42 (-1.08)	1.8 (5.19)	0.37 (0.95)	0.591

A $I_b{}^z = B_0 + B_1DA$
B $I_b = B_0 + B_1DA + B_2AVG + B_3D10 + B_4D30W + B_5R236 + B_6AR$
C $I_g{}^y = B_0 + B_1DA$
D $I_g = B_0 + B_1DA + B_2AVG + B_3D10 + B_4D30W + B_5R236 + B_6AR$

Equation testing: Elgin			Equation testing: High Noon		
Test of Equation A N=26	Lots not actually "Bad"(0)	Lots actually "Bad"(1)	Test of Equation A N=9	Lots not actually "Bad"(0)	Lots actually "Bad"(1)
Lots not predicted "Bad"(I<0)	20	6	Lots not predicted "Bad"(I<0)	2	7
Lots predicted "Bad"(I≥0)	0	0	Lots predicted "Bad"(I≥0)	0	0
Test of Equation B N=26	Lots not actually "Bad"(0)	Lots actually "Bad"(1)	Test of Equation B N=9	Lots not actually "Bad"(0)	Lots actually "Bad"(1)
Lots not predicted "Bad"(I<0)	20	2	Lots not predicted "Bad"(I<0)	2	2
Lots predicted "Bad"(I≥0)	0	4	Lots predicted "Bad"(I≥0)	0	5
Test of Equation C N=26	Lots not actually "Good"(0)	Lots actually "Good"(1)	Test of Equation C N=9	Lots not actually "Good"(0)	Lots actually "Good"
Lots not predicted "Good"(I<0)	5	19	Lots not predicted "Good"(I<0)	8	0
Lots predicted "Good"(I≥0)	1	1	Lots predicted "Good"(I≥0)	0	1
Test of Equation D N=26	Lots not actually "Good"(0)	Lots actually "Good"(1)	Test of Equation D N=9	Lots not actually "Good"(0)	Lots actually "Good"
Lots not predicted "Good"(I<0)	6	6	Lots not predicted "Good"(I<0)	8	0
Lots predicted "Good"(I≥0)	0	14	Lots predicted "Good"(I≥0)	0	1

[z] If $I_b \geq 0$, then predict > 60% of fruit in the lot to scald, and consider lot "Bad". In Equations A and B 71/197 lots are "Bad".
[y] If $I_g \geq 0$, then predict < 20% of fruit in the lot to scald, and consider lot "Good". In Equations C and D 112/197 lots are "Good".

CHAPTER VIII

SUMMARY

Preharvest climatic conditions do not themselves cause or prevent scald development. Scald is a physiological disorder of fruit. Preharvest climatic conditions do influence physiological functions of the fruit. There are theories regarding the biochemical processes which control scald development, but the actual processes are not fully understood. It is clear, however, that preharvest environmental conditions influence these processes responsible for determining scald susceptibility of apples. The literature cited in Chapter 2, as well as the data presented in Chapters 4-7, show this clearly. Some of the specific relationships between preharvest climatic conditions (and harvest starch scores) and poststorage scald development on fruit are summarized below, along with some observations of how these relationships may be influenced by local growing conditions.

Scald vs Harvest Date, Location, and Cultivar

It long has been established that late-picked fruit develop less scald than early-picked fruit. However, the exact date of fruit harvest varies after which they will be scald-free, or develop little enough scald as to be commercially acceptable. That this variation exists among fruit-growing areas is apparent from the varying harvest dates found in different areas, and from the varying amounts of scald which typically develop in fruit grown in different areas. Cultivars vary in susceptibility to scald. In some areas, scald development varies enormously from year to year. In other areas there is less variability. Table 8.1 shows examples of the above-cited differences. The cultivars and locations selected were chosen because the Massachusetts, USA and Elgin, SA data sets consistently contained the most variables, both included 'Delicious' data, and each had a contrasting cultivar to go along with the 'Delicious'. For each of the four cultivar x location categories four years of data are shown so comparisons will be roughly equivalent.

Harvest date, expressed as days after full bloom (DAFB) (or as calendar date, as shown in Chapters IV-VII), varied among cultivars. Within any given year, location, and cultivar, later harvested fruit were less scald susceptible than earlier harvested fruit, unless there was essentially no scald development throughout the season, as was the case in the 1982 and 1983 Elgin, SA-grown fruit (Table 8.1). Table 8.1 shows that the mean harvest date of 'Delicious' in Massachusetts was 2 days later than the mean harvest date of 'Cortland'. The mean harvest of 'Granny Smith' in Elgin, SA was 40 days later than the mean harvest date of 'Delicious'. The mean harvest date as DAFB for 'Delicious' was 9 days less in Elgin, SA than in Massachusetts, USA. These similarities and differences may influence the relationships between harvest date and scald development, because temperature, light, and rainfall patterns tend to change as harvest seasons progress, and preharvest temperature, light, and rainfall have been shown to influence scald development.

Comparisons of effects of location on scald variation can be made for the 'Delicious' from the two locations shown in Table 8.1. From the "All 4 years" lines it can be seen that, on average, the fruit were harvested 147 days after full bloom in Massachusetts and 138 days after full bloom in Elgin. In Massachusetts 27% of fruit developed scald, while in Elgin 21% of fruit developed scald. In Massachusetts there was year-to-year variation in scald development, and the range of averages was 14% to 75%. In Elgin, however, there was much greater year-to-year variation in scald development. In 1980, 55% of fruit developed scald, while in the other years the averages were 11%, 5%, and 10%. In 1982, the year in which only 5% of fruit developed scald, out of 40 lots of fruit, the lot with the most scald development produced only 12% scald. Not surprisingly, scald development was not significantly related to DAFB that year.

Perhaps because of the differing overall and year-to-year variation in scald development between the two locations, and the fact that in Elgin there were years in which almost no fruit developed scald, the relationships between time of harvest and poststorage scald development were quite different for the two locations. Harvest date as DAFB (or as calendar date) was a fairly good indicator of scald development in Massachusetts, while it was not in Elgin. It is likely that some factor which influences scald development changes in a more consistent manner from year to year in Massachusetts than in Elgin. This likelihood is investigated.

Temperature Effects

Preharvest temperatures and their effects on scald development in Massachusetts and Elgin were compared. Table 8.2 shows mean values of average preharvest temperatures, as well as mean values of selected preharvest low and high temperature variables for the cases shown in Table 8.1. In comparing the OLS equations in Table 8.1 showing the effect of harvest date as DAFB on scald development with the OLS equations in Table 8.2 showing preharvest temperature effects on scald development, one finds equal or higher R^2 values in Table 8.2 in every case except that of the 1981 Elgin-grown 'Delicious' and the "All 4" 'Cortland' equation. Neither the equations in Table 8.1 nor those in Table 8.2 described scald variation in Elgin as well as in Massachusetts. It may be that some scald-influencing factor other than preharvest temperature is consistently better correlated with preharvest temperature in Massachusetts than in Elgin.

Rainfall and Light Effects

Two such possible factors are preharvest rainfall and preharvest light. Table 8.3 shows that mean preharvest rainfall is much less in Elgin than in Masachusetts. In the Massachusetts 'Cortland' data set, for the combined four years the equation shows that an increase in rainfall was associated with a decrease in scald. This was also true for the four-years equation for Massachusetts 'Delicious', but in 1991 and 1993 additional rainfall was associated with increased scald. In no case in the Massachusetts individual year examples did adding the rainfall variable to an equation improve the equation's R^2 by more than 0.05. However, the R^2 of the "All 4" equation for 'Delicious' in Massachusetts increased from 0.61 to 0.73. (Note that the most scald and the least rainfall were both in 1990.) In the Elgin 'Delicious' data set, as in that for Massachusetts 'Delicious', the rainfall effect was not consistent from year to year. In 1981, the B_x for rainfall was positive, and the R^2 of the equation increased from 0.37 to 0.52, while in the 1980, 1982, and 1983 equations the B_x's for rainfall were negative, and the R^2's of the equations increased from 0.80 to 0.84, 0.11 to 0.17, and 0.11 to 0.22, respectively. The 'Granny Smith' example was more consistent: where the B_x for rainfall was significant, it was negative, and the R^2 value of the "All 4" equation increased from 0.28 to 0.67. (Note that in 1991, the high scald year, the lowest mean rainfall occurred.) The sometime ambiguity of the rainfall effect may be due to its not being a linear effect, although it is being treated as one. The equations in which the rainfall coefficients were positive also had relatively high mean rainfall values. It may be that at relatively low levels of rainfall, additional rainfall decreases scald development, and high levels of precipitation increase it, but that was not tested in these data.

Light effects shown in Table 8.3 are more ambiguous. In both Massachusetts examples the 4-year equation changed significantly with the addition of the SUN variable, and the coefficient for that variable was negative, but in both Elgin examples, the 4 year effect of light was not statistically significant at P=0.05. In the individual-year equations from both locations and for all three cultivars, the light effect varied, in some years the sign of the coefficient was positive, in some years negative, and in some years not significant. Thus, the light effect at the light levels present in these examples did not consistently influence scald development.

Maturity as Starch Score

The simple effect of starch score on scald development, as well as the effect of starch score in equations which also include factors for temperature and rainfall variation, were compared for the two locations and three cultivars (Table 8.4). In nearly all cases starch score and scald were negatively correlated. In equations including factors for preharvest temperature and rainfall, as well as starch score, starch score was not often statistically significant. However, in the "All 4" equations for 'Cortland', 'Granny Smith' and the Elgin 'Delicious', the starch score coefficients were negative and were statistically significant. If these equations are compared with the equations in Table 8.3 which include all these variables except starch, it is seen that R^2's increased substantially for these three equations. Chow's tests (not shown) comparing these three pairs of equations confirm that the equations including the ST variable are significantly different from the corresponding equations in Table 8.3. Thus in the cases of Massachusetts 'Cortland' and Elgin 'Delicious' and 'Granny Smith', not only was increasing starch score associated with decreased scald development, but this effect was, over four years, significantly independent of temperature and rainfall effects. In Massachusetts 'Delicious' starch score was, except in 1988, negatively correlated with scald development, but addition of the ST variable to corresponding equations in Table 8.3 did not significantly change those equations (Chow's tests not shown).

Predicting Scald Severity

The following equations were generated using all four years of data: Percent scald = $B_0 + B_1DAFB + B_2AVG + B_3D10 + B_4D25W + B_5ST + B_6RAIN + B_7SUN$. They gave R^2's of 0.68 for Massachusetts 'Cortland', 0.75 for Massachusetts 'Delicious', 0.85 for Elgin 'Delicious', and 0.78 for Elgin 'Granny Smith'. These R^2's represent explanations of from 68 to 85% of the variation in scald development for these areas and cultivars. Both Massachusetts equations and the Elgin 'Granny Smith' equation have significant Durbin-Watson d values. In these cases, the equations overestimate the low scald values, while underestimating high values. These mis-estimations may or may not prove troublesome. For a prediction system to be of commercial value it is not necessary to predict the exact number of fruit which will scald. A general estimate is sufficient to determine appropriate anti-scald treatment for lots of apples.

Fruit were classified into categories: "Good" were those lots of fruit with fewer than 20% of fruit developing scald, "Bad" were those lots of fruit with over 60% of fruit developing scald. For each of the four area-by-cultivar groups previously cited in this chapter, Logit equations were developed from 3 years of data to "predict" scald severity in the fourth year. No equations could be developed for the 'Granny Smith' because, as Table 8.5 shows, there were not enough fruit in the "Bad" category or outside the "Good" category.

The top of Table 8.6 shows how well the equations were able to fit the data used for generating the equations, and the bottom of the table shows success of "predicting" fourth year scald severity. The selection of variables used in Table 8.6 was based on t-values of coefficients in equations in which all variables were included. Generally, if the absolute value of t was below 1.00, the variable was dropped.

The 'Cortland' equations in Table 8.6 were the least successful, in terms of correct placement of the 1993 test data, but placed over 60% of lots in the correct categories. Signs of coefficients were opposite in the "Bad" and "Good" equations. Confirming previous observations, one could predict that higher temperatures and lower starch scores would lead to greater scald susceptibility.

The Massachusetts 'Delicious' equations in Table 8.6 show the effects of selecting different variables for prediction. Equations B and C gave the same predictions for the 1993 scald-susceptible fruit, showing that intercorrelations among variables make it possible to predict based on a variety of combinations of variables. Equation G includes the variables of Equation F with the addition of the RAIN variable, and has a much higher NSI than Equation F, yet gives different, but not better, predictions for 1993. This suggests that correlations between year-to-year differences in rainfall and other variables may be detrimental to the prediction system. More years of data would be needed to test that. On the whole the Massachusetts 'Delicious' prediction equations were quite successful.

The success of the Elgin 'Delicious' equations is difficult to assess. They are quite different from the Massachusetts 'Delicious' equations, both in variables used, and in sign of the D10 coefficients and the "Good" AVG coefficient. The "Bad" Elgin 'Delicious' equation in Table 8.6 illustrates the situation in which all of the "Bad" lots of fruit were from the same season. The NSI for the equation (0.846) shows that the equation fit the data well. In the test year, 1983, no fruit were in the "Bad" category. This was correctly predicted. However, it is troubling that the corresponding equations for the "Good" lots of Elgin 'Delicious' (NSI = 0.729) also placed all the test year lots of fruit into a single category. The equation correctly categorized 52 of the 55 lots categorized as "Good", but failed to identify any of the 3 "Not Good" lots.

Conclusions

From the overall results of this study, as well as the subset of data described in Tables 8.1 through 8.6 as illustrations, a number of conclusions can be made concerning both descriptions of scald variation and prediction of scald incidence.

Description of Scald Variability

Scald incidence varies enormously from year to year within cultivar and growing area. In the illustrations shown in this chapter the variation was greater in Elgin, SA than in Massachusetts, USA, but even in Massachusetts the mean percentage of 'Delicious' afflicted with scald varied from 14% in 1988 to 75% in 1990. Overall, 'Cortland' apples developed more scald than 'Delicious'. Throughout the study, it was confirmed that in years when considerable scald (affecting over 10% of fruit) developed, later harvested fruit developed less scald, and more mature fruit (those with higher harvest starch scores) developed less scald. Within a given year and location, simple correlations between percent of fruit developing scald and average preharvest temperature were negative, as were simple correlations between scald and number of preharvest cool days. In contrast, where statistically significant, simple correlations between scald and number of preharvest hot days were positive. When several temperature variables were combined in a single equation describing scald variation, the signs of the coefficients for temperature variables were not predictable. Preharvest rainfall varied greatly from year to year and from location to location, and its effect on scald development was not consistent. In the illustration given in Table 8.3, the rainfall coefficient was (where significant) negative where rainfall was lower and positive where rainfall was higher, suggesting that perhaps the effect is not linear. This hypothesis has not been tested. Light was only measured in two locations, and in different ways in each. Coefficients for light intensity effects as shown in Tables 6.20, 6.24, and 6.25 were nearly always negative, consistent with the view that increasing light intensity reduces scald development.

When equations were generated using more than one independent variable to describe variation in scald development, the signs of the coefficients of individual variables often were different from the signs of the simple correlations with scald. Most "independent" variables were correlated with one another. In general, the more variables in an equation, the less predictable was the sign of a given coefficient. However, the more samples used to generate an equation describing scald development, and the more varied the values of the variables, the more likely it was that the signs of the coefficients would be as expected. An exact relationship is unlikely to be found since there are undoubtably other unmeasured factors which also influence the physiological processes which determine scald susceptibility. However, knowing that apples harvested following lower preharvest temperatures, greater rainfall, and more light are generally less likely to scald than others, it may be possible to adjust anti-scald treatments so as to reduce chemical without greatly increasing the risk of excessive scald development.

Prediction of Scald Severity

Predicting scald incidence on fruit grown in a given region was not successful if the prediction equation was not based on data from lots of fruit grown in that region. Combining data from many regions was useful in identifying overall climate and maturity effects on scald susceptibility, but it could not be used for prediction of scald incidence. Thus the number of cases available for generating equations designed to predict scald incidence is only as large as the number of cases available from a given cultivar grown in a given area. Where great year-to-year variation exists in scald severity, many years of data will be needed to generate equations for predicting scald susceptibility. The differences in signs of the coefficients in descriptive equations from cultivar to cultivar, and from location to location within cultivar, show that prediction of scald susceptibility must be made on a local basis, separately for each of the cultivars. Signs of prediction equation coefficients were generally consistent within a location x cultivar, so these, as well as complete equations, could be used as a guide in determining postharvest treatment of fruit with reference to anti-scald treatment.

Table 8.1 Relationships between harvest date and cultivar and fruit growing region, and among years within a cultivar and a fruit-growing region.

Cultivar	Location	Year	N	Harvest date (DAFB[z])			Pct scald			Correlation coef. (r) Pct scald vs DAFB	R^2 of equation: Pct scald = $B_0 + B_1$DAFB
				Min	Max	Mean	Min	Max	Mean		
Cortland	MA, USA	1990	27	115	153	141	31	100	68	-0.82	0.68
		1991	60	125	167	151	6	100	44	-0.89	0.79
		1992	27	121	164	137	0	87	41	-0.81	0.65
		1993	35	128	156	144	39	100	70	-0.75	0.57
		All 4	147	115	167	145	0	100	54	-0.73	0.54
Delicious	MA, USA	1988	77	136	151	143	0	73	14	-0.17	0.03
		1990	24	134	154	143	30	100	75	-0.82	0.68
		1991	45	147	173	158	0	72	17	-0.79	0.62
		1993	40	127	158	145	1	100	35	-0.95	0.90
		All 4	186	127	173	147	0	100	27	-0.55	0.30
Delicious	Elgin, SA	1980	60	125	155	138	0	100	55	-0.84	0.71
		1981	75	129	161	143	0	44	11	-0.74	0.54
		1982	40	116	151	132	0	12	5	-0.22[ns y]	0.05
		1983	55	120	155	136	0	24	10	-0.15[ns]	0.02
		All 4	230	116	161	138	0	100	21	-0.34	0.11
Granny Smith	Elgin, SA	1981	40	153	205	180	0	32	4	-0.58	0.34
		1982	30	153	194	174	0	8	1	-0.38	0.14
		1983	40	156	202	180	0	12	2	+0.06[ns]	0.00
		1991	35	155	197	176	47	100	94	-0.62	0.39
		All 4	145	153	205	178	0	100	25	-0.13[ns]	0.02

[z] DAFB = Days after full bloom.

[y] All correlation coefficients in this column labelled [ns] are not significant at P=0.05, all others are significant at P=0.05.

Table 8.2 Comparison of preharvest temperature effects on scald development in apples grown in Elgin, SA and Massachusetts, USA.

Cultivar	Location	Year	N	Mean value of the variable[z]:				R^2 of equation: %Scald=B_0 + B_1AVG + B_2D10 + B_3D25W	Significance at P=0.05 of B_x of:		
				Scald	AVG	D10	D25W		AVG	D10	D25W
Cortland	MA, USA	1990	27	68	20	10	2.2	0.79	+	ns	-
		1991	60	44	19	14	1.6	0.85	+	ns	ns
		1992	27	41	17	26	1.6	0.82	ns	ns	+
		1993	35	70	19	18	0.7	0.70	+	+	+
		All 4	149	54	19	16	1.5	0.52	+	ns	+
Delicious	MA, USA	1988	77	14	19	24	2.3	0.12	ns	ns	ns
		1990	24	75	19	13	1.5	0.68	ns	ns	ns
		1991	45	17	18	19	0.7	0.80	+	+	-
		1993	40	35	18	19	0.8	0.91	ns	ns	+
		All 4	186	27	19	20	1.5	0.61	ns	-	ns
Delicious	Elgin, SA	1980	60	55	19	12	5.1	0.80	-	-	+
		1981	75	11	19	2	3.8	0.37	-	-	ns
		1982	40	5	19	7	3.3	0.11	ns	ns	ns
		1983	55	10	19	6	3.1	0.11	ns	ns	+
		All 4	230	21	19	7	3.9	0.22	+	+	ns
Granny Smith	Elgin, SA	1981	40	4	18	20	2.0	0.51	-	-	+
		1982	30	1	18	14	1.5	0.44	-	-	+
		1983	40	2	17	17	3.4	0.03	ns	ns	ns
		1991	35	94	19	22	3.4	0.50	ns	ns	ns
		All 4	145	25	19	18	2.6	0.28	+	+	+

[z] Abbreviations for variables are: Scald= percent scald, AVG= mean preharvest temperature from 03 August to harvest (Mass.) or from 01 January (Elgin) to harvest, D10= number of preharvest days at or below 10°C, D25W=number of days at or above 25°C in the week before harvest.

Table 8.3 Comparison of preharvest rainfall and light effects on scald development in apples grown in Elgin, SA and Massachusetts, USA.

Cultivar & location	Year	N	Mean value of the variable:			R^2 of equation: %Scald=B_0 + B_1AVG[z] + B_2D10 + B_3D25W + B_4RAIN	Significance at P=0.05 of B_x of:	R^2 of equation: %Scald=B_0 + B_1AVG[z] + B_2D10 + B_3D25W + B_4RAIN + B_5SUN	Significance at P=0.05 of B_x of:	
			Scald	RAIN	SUN		RAIN		RAIN	SUN
Cortland Mass, USA	1990	27	68	2.2	0.5	0.81	ns	0.83	ns	ns
	1991	60	44	4.2	0.5	0.85	ns	0.86	ns	-
	1992	27	41	1.8	0.4	0.82	ns	Data insufficient to create equation.		
	1993	35	70	4.1	0.4	0.72	ns	0.77	ns	+
	All 4	149	54	3.4	0.5	0.55	-	0.58	-	-
Delicious Mass, USA	1988	77	14	3.2	0.6	0.16	-	0.16	ns	ns
	1990	24	75	2.1	0.5	Data insufficient to create equations.				
	1991	45	17	5.1	0.4	0.82	+	0.84	+	+
	1993	40	35	4.1	0.4	0.96	+	0.99	+	+
	All 4	186	27	3.7	0.5	0.73	-	0.74	-	-
Delicious Elgin, SA	1980	60	55	1.4	8.3	0.84	-	0.85	-	ns
	1981	75	11	3.8	8.0	0.52	+	0.58	+	-
	1982	40	5	0.3	8.2	0.18	-	0.27	ns	+
	1983	55	10	3.6	8.6	0.20	-	0.22	-	ns
	All 4	230	21	2.5	8.3	0.22	ns	0.23	ns	ns
Granny Smith Elgin, SA	1981	40	4	2.8	7.7	0.55	-	0.56	ns	ns
	1982	30	1	0.9	7.7	0.45	ns	0.53	ns	+
	1983	40	2	2.8	7.9	0.05	ns	0.05	ns	ns
	1991	35	94	0.7	9.7	0.51	ns	0.63	ns	-
	All 4	145	25	1.9	8.3	0.67	-	0.67	-	ns

[z] Abbreviations for variables in addition to those given in Table 8.2 are: RAIN= mean daily rainfall in mm from 24 August (Mass.) or from 22 January (Elgin) to harvest, SUN (Mass.)= mean daily light score from 03 September to harvest, SUN (Elgin)= mean daily MJ light from 01 February to harvest.

Table 8.4 Comparison of harvest starch score effects on poststorage scald development in apples grown in Massachusetts, USA and Elgin, SA.

Cultivar & location	Year	N	Mean value of the variable:		Correlation coefficient (r) Scald vs Starch (ST^z)	R^2 of equation: %Scald= $B_0 + B_1ST$	R^2 of equation: %Scald= $B_0 + B_1AVG^y + B_2D10 + B_3D25W + B_4RAIN + B_5ST$	Signif. at P=0.05 of B_x of:
			Scald	Starch				Starch (ST)
Cortland Mass, USA	1990	27	68	3.3	-0.74	0.55	0.81	ns
	1991	60	44	4.9	-0.89	0.79	0.85	ns
	1992	27	41	3.9	-0.81	0.66	0.83	ns
	1993	35	70	3.6	-0.69	0.48	0.73	ns
	All 4	149	54	4.2	-0.78	0.61	0.68	-
Delicious Mass, USA	1988	77	14	2.7	+0.09[ns x]	0.01	0.16	ns
	1990	24	75	2.9	-0.77	0.59		
	1991	45	17	4.3	-0.72	0.51	0.83	ns
	1993	40	35	2.1	-0.81	0.65	0.96	ns
	All 4	186	27	3.0	-0.33[ns]	0.11	0.73	ns
Delicious Elgin, SA	1980	60	55	3.3	-0.91	0.82	0.85	ns
	1981	75	11	2.2	-0.80	0.63	0.70	-
	1982	40	5	2.1	-0.26[ns]	0.07	0.23	ns
	1983	55	10	2.2	-0.15[ns]	0.02	0.23	ns
	All 4	230	21	2.5	-0.31	0.09	0.84	-
Granny Smith Elgin, SA	1981	40	4	3.3	-0.56	0.31	0.56	ns
	1982	30	1	2.2	-0.38	0.14	0.53	-
	1983	40	2	3.4	+0.06[ns]	0.00	0.05	ns
	1991	35	94	2.2	-0.68	0.47	0.63	-
	All 4	145	25	2.8	-0.33	0.11	0.78	-

[z] Starch or ST = starch score of fruit at harvest.
[y] Abbreviations area as given in Tables 8.1 and 8.2.
[x] Coefficients in this column labelled [ns] are not significant at P=0.01. All others are significant at P=0.01.

Table 8.5 A summary of groups of "Good"[z] and "Bad"[y] lots of fruit by cultivar, area, and year.

Cultivar & location	Year	N	"Good"		"Bad"	
			N	%	N	%
Cortland MA, USA	1990	27	0	0	15	56
	1991	60	10	17	16	27
	1992	27	10	37	9	33
	1993	35	0	0	23	66
	All 4	149	20	13	63	42
Delicious MA, USA	1988	77	59	77	4	5
	1990	24	0	0	49	79
	1991	45	28	62	2	4
	1993	40	20	50	12	30
	All 4	186	107	58	37	20
Delicious Elgin, SA	1980	60	19	32	34	57
	1981	75	57	76	0	0
	1982	40	40	100	0	0
	1983	55	52	95	0	0
	All 4	230	168	73	34	15
Granny Smith Elgin, SA	1981	40	37	93	0	0
	1982	30	30	100	0	0
	1983	40	40	100	0	0
	1991	35	0	0	34	97
	All 4	145	107	74	34	23

[z] "Good" lots of fruit are those from which fewer than 20% of fruit scalded.
[y] "Bad" lots of fruit are those from which more than 60% of fruit scalded.

Table 8.6 Logit equations created from 3 years of data to predict scald severity in a fourth year.

Equation	Cultivar Location	N	B_0	B_1 (t)	B_2 (t)	B_3 (t)	B_4 (t)	B_5 (t)	B_6 (t)	NSI
			Fruit lot predicted "Bad" if Index (I): $B_0 + B_1DA + B_2AVG + B_3D10 + B_4D25W + B_5ST + B_6RAIN \geq 0$							
A	Cortland MA, USA	114	-22		1.27 (2.53)		0.526 (2.02)	-0.909 (-3.67)		0.653
B	Delicious MA, USA	146	9.8			-0.39 (-4.40)			-1.2 (-4.11)	0.627
C	Delicious MA, USA	146	-7.1	-0.022 (-0.06)	0.76 (0.32)	-0.62 (-2.59)	1.7 (2.02)			0.516
D	Delicious Elgin, SA	175	-361		18.7 (1.26)	1.16 (1.78)		-4.45 (-1.96)		0.846
			Fruit lot predicted "Good" if Index (I): $B_0 + B_1DA + B_2AVG + B_3D10 + B_4D25W + B_5ST + B_6RAIN \geq 0$							
E	Cortland MA, USA	114	21		-1.3 (-2.80)		-0.75 (-1.76)	0.48 (1.37)		0.459
F	Delicious MA, USA	146	-131	1.20 (2.23)	3.25 (1.71)	0.71 (2.63)	-4.97 (2.64)			0.466
G	Delicious MA, USA	146	-2523	13 (0.87)	81 (1.12)	8.1 (0.70)	-31 (-0.96)		45 (1.03)	0.607
H	Delicious Elgin, SA	175	321		-17 (-3.17)	-0.86 (-2.96)		3.3 (3.78)		0.729

Tests of above equations:

	Equation A Observed Index		Equation B Observed Index		Equation C Observed Index		Equation D Observed Index	
	0(Not Bad)	1(Bad)	0(Not Bad)	1(Bad)	0(Not Bad)	1(Bad)	0(Not Bad)	1(Bad)
Predicted Index <0 (Not Bad)	12	13	27	3	27	3	55	0
Predicted Index ≥0 (Bad)	0	10	1	9	1	9	0	0

	Equation E Observed Index		Equation F Observed Index		Equation G Observed Index		Equation H Observed Index	
	0(Not Good)	1(Good)	0(Not Good)	1(Good)	0(Not Good)	1(Good)	0(Not Good)	1(Good)
Predicted Index <0 (Not Good)	26	0	15	0	20	5	0	0
Predicted Index ≥0 (Good)	9	0	5	20	0	15	3	52

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