Modification of rest completion prediction models for improved accuracy in South African stone fruit orchards

MODIFICATION OF REST COMPLETION PREDICTION MODELS FOR IMPROVED ACCURACY IN SOUTH AFRICAN STONE FRUIT ORCHARDS

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ABSTRACT

The 'Utah' rest completion prediction model of Richardson et al.(1974), to quantify the severity of winter chilling experienced, does not give a true reflection of the winter chilling in the milder zones of the South African fruit growing areas.

Climatic and phenological data were collected for three nectarine cultivars in six climatically divergent locations over a period of four seasons. The end of winter dormancy was presumed when 10% flower bud break occurred after 14 days of forcing in a growth chamber at 25°C. omit

Climatic data for this period was analysed and the standard deviations and coefficients of variation calculated. The 'dynamic' model gave considerably lower coefficients of variation than the 'Utah' model, but a modification thereof, using considerations from the 'dynamic' model, reduced these to to the similar levels as that of the 'dynamic' model.

The modification assumes that the negating effect of high temperatures is confined to the diurnal cycle and that there cannot be a carry-over of negation from one day to the next. The modification allows for the continued albeit modified use of the Utah model by the South African deciduous fruit industry.

INTRODUCTION

Deciduous fruit trees need to be subjected to low temperatures for a certain period of time for release from winter dormancy. Moderate to high day temperatures during winter, common in South African deciduous fruit growing regions, are known to have a negative effect on rest development in dormant buds (Couvillon & Erez, 1985).

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The use of number of hours below 7,2°C as a measure of the rest requirement, as is extensively used in the traditional deciduous fruit growing regions of the world (Weinberger,1950), is therefore not accurate in many warm temperate locations. The South African deciduous fruit industry has opted for the 'Utah' prediction model of Richardson, Seeley & Walker (1974), as it takes into account the negating effect of high temperatures on chill unit accumulation (Matthee, 1982). This model assigns half a chill unit to each hour at temperatures 1,5 to 2,4°C and 9,2 to 12,4°C; and one chill unit to temperatures between 2,5 and 9,1°C. As the temperatures exceeds 16°C, half a unit is subtracted for each hour between this threshold and 18°C, after which a full unit is subtracted (Richardson *et al.*, 1974). The 'Utah' model has been widely used by the local industry, but tends to be less accurate in the warmer stone fruit growing areas (Erez, Fishman, Linsley-Noakes & Allan, 1990; Linsley-Noakes & Allan, 1994). Low chill stone-fruit cultivars are successfully grown in areas which occasionally receive a negative total 'Utah' chill unit accumulation in winter (Allan, Linsley-Noakes, Mathee & Rufus, 1993).

The 'dynamic' model adds a further element viz. timing of exposure to temperatures in a cycle, which appears to have an important influence on rest completion (Fishman, Erez & Couvillon, 1987). This model is based on sound experimental results and has proven to be superior to preceding models since it not only takes into account the negating effect of high day temperatures, but also recognises the positive effect of moderate temperatures in the chilling cycle.

The 'dynamic' model assumes that the level of rest completion depends on the level of a certain dormancy breaking factor which is accumulated in buds by a two-step process. The first step is a reversible process of formation and destruction of a thermally labile precursor. When a critical portion of the precursor is amassed, it is transferred irreversibly in the second step, to one portion of a stable factor. The dynamics of this process simulate rest development and agree with the complex effects of temperature on rest completion.

Initial investigations have shown that the 'dynamic' model may have particular use in the marginal deciduous fruit growing regions of South Africa (Erez *et al.*, 1990; Allan *et al.*, 1993; Linsley-Noakes & Allan, 1994).

The problem with the 'dynamic' model is that it requires a complex computer programme to calculate the units, which makes it less accessible as a management tool for fruit growers. Although the 'Utah' chill units are also calculated by computer from hourly temperatures, they can be calculated manually or estimated from a table of values, based on daily minimum and maximum temperatures (Linsley-Noakes, unpublished data). The aim was therefore to attempt to modify the 'Utah' model in order to develop a model which is "user friendly" yet approaching the accuracy of the 'Dynamic' model.

The main point of difference between the two models is that the 'dynamic' model takes into account the effect of chilling cycle length on negation by high temperatures. Erez *et al.* (1979) showed that only high temperatures within a 36 hour cycle significantly reduced bud break and that there was an insignificant carry-over effect from one day to the next. It was therefore assumed that by cancelling out the carry-over effect of negating high temperatures in the 'Utah' model it would improve accuracy in areas where high temperatures in the daily cycle were prevalent. Linsley-

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Noakes and Allan (1993) also showed that the 'Utah' model consistently underestimated the chilling requirements of the nectarine cultivars Sunlite, Flavortop and Fantasia nectarines in warmer locations. These locations can experience temperatures of 25°C and higher in winter and the effect of these high temperatures on rest breaking have not been fully examined.

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MATERIALS AND METHODS

Climatic and phenological data were collected from nectarine orchards at six locations in the fruit growing regions of the Western Cape Province of South Africa from 1988 to 1991.

These locations were widely divergent in their winter climate and the severity of the winters differed over the four seasons examined. The differences in climate were caused by a combination of aspect, altitude, latitude and winter rainfall. Three commercially important nectarine cultivars, Sunlite, Flavortop and Fantasia, described locally as having low, medium and medium/high winter chilling requirements respectively, were selected. Each area represented orchards in which these cultivars were located in adjacent blocks, representing a uniform microclimate, and of similar age and training system.

Within each orchard a Stevenson screen was erected and hourly air temperature was measured in the screen by means of thermocouples linked to locally made electronic data loggers (M.C. Systems, P.O. Box 73, Steenberg 7947, South Africa). Casella min/max thermometers were used as a check.

Temperature data were converted into 'Utah' chill units, 'dynamic' portions and 'modified' units. Accumulation of 'Utah' chill units commenced after the last large negative accumulation in May and usually coincided with the first 'dynamic' portion accumulation.

Thirty 300 mm shoots from each cultivar at each location were collected at two-weekly intervals throughout the winter to examine their phenological status. The shoots were forced in a growth chamber at 25°C. Ten percent (10%) flower bud break after 14 days forcing at 25°C was adopted as the end of rest index (Linsley-Noakes and Allan, 1993). The accumulation of 'Utah' chill units 'dynamic' portions and modified units was calculated for these periods in order to statistically compare models.

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RESULTS

By assuming no negation of chilling by the following day's high temperatures, the chilling accumulation pattern of the 'Utah' units more closely followed those of the 'dynamic' model. This was most evident at the warmer locations (Fig. 1), where the difference between the models was most accentuated. Periods of high temperatures during winter result in a drop off in the 'Utah' chill unit accumulation during endodormancy. Projection of end of endodormancy dates onto the 'Utah' chill accumulation data indicated very little difference in chilling requirement between the cultivars, yet there was a big time difference between termination of endodormancy in Flavortop/ Fantasia and Sunlite. The 'modified Utah' data on the other hand, did show differences in chilling requirement between the cultivars. Analysis of the endodormancy chilling data showed that the modification of the 'Utah' model reduced the coefficients of variation in the cultivar Sunlite from 26.72 to 21.63%, in Flavortop from 19.31 to 15.95% and in Fantasia from 21.18 to 17.90% (Tables 1, 2 and 3).

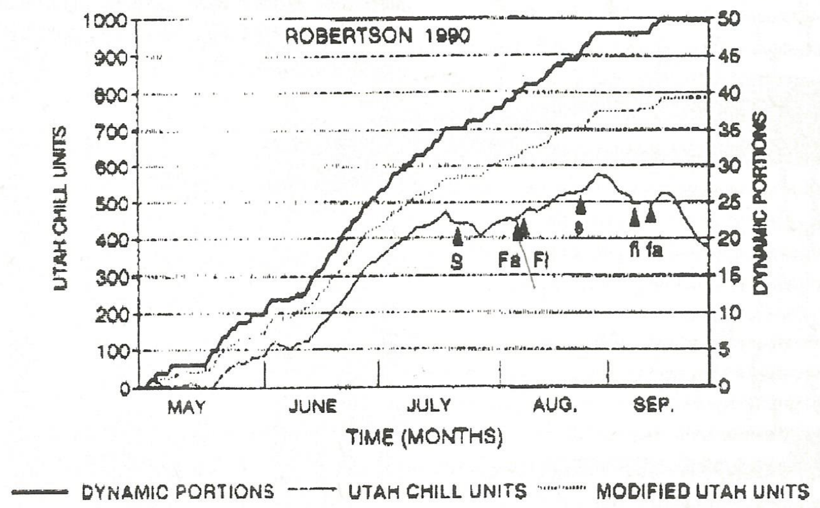

FIGURE 1: Accumulation trends for 'dynamic' portions, 'Utah' chill units and 'modified Utah' chill units for the mild temperate nectarine growing region of Robertson in 1990. S, Fl and Fa represent termination of endodormancy and s, fl and fa represent full bloom dates for the nectarine cultivars Sunlite, Flavortop and Fantasia respectively.

TABLE 1: Accumulation of 'dynamic' portions, 'Utah' and 'modified Utah' chill units for the nectarine cultivar Sunlite, from six climatically different locations and over four seasons.

		MODEL		
LOCATION	SEASON	DYNAMIC	UTAH	MODIFIED UTAH
ROBERTSON	1988	22.2	247.5	323.5
	1989	27.8	369.0	431.0
	1990	33.6	468.5	481.0
	1991	27.6	406.0	580.0
PAARL	1988	27.0	355.0	521.5
	1989	27.6	414.0	472.5
	1990	34.8	575.0	585.5
CLANWILLIAM	1988	25.8	441.5	487.5
	1989	26.3	458.0	488.0
	1990	34.6	632.0	648.5
VILLIERSDORP	1988	31.4	528.5	586.0
	1989	34.1	597.5	624.5
	1990	34.3	482.0	506.0
CERES	1988	41.2	719.0	729.0
	1989	35.9	577.5	582.0
	1990	39.6	542.5	542.5
BOKKEVELD	1988	49.1	1013.2	1014.5
	1989	37.1	695.5	717.5
	1990	36.3	605.5	616.5
	1991	37.1	615.0	712.0
MEAN		33.17	536.33	582.48
STANDARD DEVIATION		6.20	159.24	139.99
COEFFICIENT OF VARIATION (%)		16.82	26.72	21.63

corrections on original =

TABLE 2: Accumulation of 'dynamic' portions, 'Utah' and 'modified Utah' chill units for the nectarine cultivar Flavortop, from six climatically different locations and over four seasons.

LOCATION	SEASON	DYNAMIC	UTAH	MODIFIED UTAH
ROBERTSON	1988 delayed foliation			
	1989	38.7	538.0	626.5
	1990	41.2	487.5	580.0
	1991	40.8	538.0	590.0
PAARL	1988 delayed foliation			
	1989	43.1	692.5	778.5
	1990	42.0	681.0	697.0
CLANWILLIAM	1988	33.0	583.0	641.0
	1989	41.6	686.5	798.0
	1990	38.1	705.0	721.5
VILLIERSDORP	1988	43.1	709.5	777.5
	1989	48.4	894.5	943.0
	1990	53.7	856.0	890.5
CERES	1988	47.8	817.0	828.5
	1989	50.2	810.5	818.5
	1990	62.7	975.0	975.0
BOKKEVELD	1988	50.1	1020.5	1022.0
	1989	41.0	789.0	827.0
	1990	58.6	1086.0	1097.0
	1991	53.9	888.0	920.0
MEAN		41.40	764.31	807.28
STANDARD DEVIATION		7.51	166.05	144.86
COEEFICIENT OF VARIATION (%)		14.51	19.31	15.95

TABLE 3: Accumulation of 'dynamic' portions, 'Utah' and 'modified Utah' chill units for the nectarine cultivar Fantasia, from six climatically different locations and over four seasons.

LOCATION	SEASON	DYNAMIC	UTAH	MODIFIED UTAH
ROBERTSON	1988 delayed foliation			
	1989	38.7	538.0	626.5
	1990	40.2	487.5	571.0
	1991	41.0	548.0	580.0
PAARL	1988 delayed foliation			
	1989	43.1	692.5	778.5
	1990	42.0	676.0	680.0
CLANWILLIAM	1988	33.0	583.0	641.0
	1989	41.6	686.5	798.0
	1990	34.6	641.5	658.0
VILLIERSDORP	1988	43.1	709.5	777.5
	1989	53.4	958.0	1011.0
	1990	55.5	882.5	917.0
CERES	1988	47.8	817.0	828.5
	1989	40.0	656.0	664.5
	1990	58.8	916.5	916.5
BOKKEVELD	1988	54.2	1058.5	1066.5
	1989	50.6	927.5	1010.5
	1990	60.6	1125.0	1136.0
	1991	55.0	901.0	933.0
MEAN		41.66	766.44	816.92
STANDARD DEVIATION		8.14	182.66	164.50
COEFFICIENT OF VARIATION (%)		15.63	21.18	17.90

The mean chill unit accumulation for the cultivars Sunlite, Flavortop and Fantasia were 33, 41 and 42 'dynamic' portions; 536, 764 and 766 'Utah' chill units and 582, 807 and 816 'modified Utah' chill units respectively.

CONCLUSION

It is apparent that minor changes to the existing 'Utah' model, currently used by the South African deciduous fruit industry, can improve its accuracy to similar levels as that of the more recently introduced but less "grower friendly" 'dynamic' model. By deleting the carry-over effect of negating temperatures from one day to the next, the effective winter chilling received at a location can be more accurately estimated.

Using the 'modified Utah' model, the average chilling requirement for the nectarine cultivars Sunlite, Flavortop and Fantasia for the Western Cape growing areas are 582, 807 and 817 chill unit respectively. The chilling requirements of Flavortop and Fantasia are practically identical.

Further research into endodormancy in warm temperate climates is required, to develop a model that predicts the chilling requirement accurately (low coefficients of variation) and also accurately predicts full bloom dates.

REFERENCES

ALLAN, P., LINSLEY-NOAKES G.C., MATTHEE, G. & RUFUS, G., 1991. Winter chilling models in a mild subtropical area and the effects of constant 6°C chilling on peach bud break. Paper presented at the ISHS Symposium on Temperate Zone Fruits in the Subtropics, Cairo, 22-26 May 1993.

COUVILLON, G.A. & EREZ, A., 1985b. Effect of level and duration of high temperatures on rest in the peach. *J. Am. Soc. Hort. Sci.*, 110: 579-581.

EREZ, A., COUVILLON, G.A. & HENDERSHOTT, C.H., 1979. The effect of cycle length on chilling negation by high temperatures in dormant peach leaf buds. *J. Am. Soc. Hort. Sci.* 104: 573-576.

EREZ, A., FISHMAN, S., LINSLEY-NOAKES, G.C. & ALLAN, P., 1990. The 'dynamic' model for rest completion in peach buds. *Acta Hort.* 276: 165-175.

FISHMAN, S., EREZ, A., & COUVILLON, G.A., 1987. The temperature dependance of dormancy breaking in plants: Two-step model involving a co-operative transition. *J. Theor. Biol.* 124: 473-483.

LINSLEY-NOAKES, G.C. & ALLAN, P., 1993. Comparison of two models for the prediction of rest completion in peaches *Scientia Hortic.*, In Press.

MATTHEE, G., 1982. Koue eenhede in die Winterreënvalgebied. Tegniese mededeling Nr. 177. Departement Landbou en Visserye, Suid Afrika.

RICHARDSON, E.A., SEELEY, S.D. & WALKER, D.R., 1974. A model for estimating the completion of rest for 'Redhaven' and 'Elberta' peach trees. *Hort. Science* 9: 331-332.

WEINBERGER, J.H., 1950. Chilling requirements of peach varieties. *Proc. Am. Soc. Hort. Sci.* 56: 122-128.