Apple growing potentials in Europe. 3. Northern limits

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Abstract

The northern production limits were determined of four apple cultivars: 'White Transparent', 'Cox's Orange Pippin', 'Golden Delicious', and 'Granny Smith'. Reactions of an apple cultivar to temperatures are: a first temperature-sensitive period in which a certain temperature sum must be reached; a second less sensitive period in which temperatures must reach a certain level during a certain period and a third sensitive period. A model was developed in which temperatures of the most northern growing place were brought in and this model was afterwards checked with data of other growing places. When differences between measured and estimated values were acceptable, the model was used to calculate whether ripening of an apple cultivar could be expected in a specific area. Thus the northern production limits could be determined.

Introduction

In literature on climatic limits of apple production in Europe, only two not too accurate references were found. Thran (1959) mentioned that the temperature requirements for growth of apple trees are 170 days above 5 °C. In Winkler-Prins (1959), the northern limits of fruit trees are outlined on a map, however, not specified into apple, pear, cherry, etc. Main results of both references are plotted in Figure 1. These publications do not indicate whether the limits hold for growing trees or fruits. It is supposed that demands for commercial fruit production are higher than for growing trees only.

In this paper it is tried to make clear, or at least suggest an explanation, why the limits of apple production are where they are. And because it is known that not one limit holds for all apple cultivars, four cultivars were chosen:
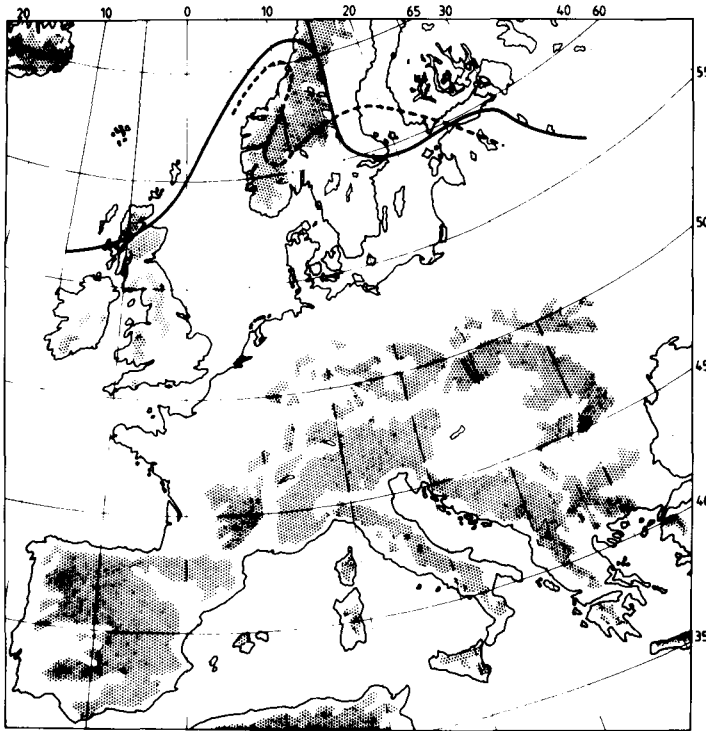- very early 'White Transparent',

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Fig. 1. Northern limits of growth of apple trees: — after Thran (1959), – – after Winkler Prins (1959).

- mid-season 'Cox's Orange Pippin',
- late 'Golden Delicious', and
- very late 'Granny Smith'.

Designing a model

The two most important plant growth determining factors are light and temperature. Landsberg (1979) states that radiation especially influences the yield. Kronenberg (1988) found that temperature is of utmost importance for apple growing. Because of that, the northern limits for production of apples also are determined by prevailing temperatures only. Kronenberg worked with base temperatures below which no growth was observed and with mean day temperatures. He calculated temperature sums by adding the per day temperatures above the base temperatures and used one month as a relevant period.

Sometimes rather low base temperatures of 6 °C or lower were found, as observed earlier for apple (Kronenberg, 1985a) and for other plants (Kronenberg, 1985b). Mean day temperatures above 6 °C (or lower) were added and in most cases high temperature sums were found. These temperature sums and a specific

minimum (base) temperature were used as variables in the model. Low base temperatures prevail shortly after flowering and before picking. In between, high base temperatures (7-26 °C) together with rather low temperature sums are observed. High 'base' temperatures in this context are related to long-lasting processes on which only very high temperatures have a perceptible influence.

The high base temperatures require a hot spell so that at least a few days with high temperature contribute to reach the required temperature sum. Kronenberg (1988) also found that the higher the prevailing temperatures, the higher 'base' temperatures were found. The phenomenon that the period between flowering and picking is hardly shortened for apples in hotter climates is reported by Winter (1981).

Therefore, when a high 'base' temperature was found in a certain month, that temperature was used in the model for a period of 30 days. In the model used for estimating the northern production limits, in period 1 and 4, beside these base temperatures a specified temperature sum is used; in period 2 and 3, mean temperature during a specified period is used (period numbering taken from Table 6).

From the basic model to a model for a specified cultivar

The most northern fruit growing station with data available of flowering, picking and production were used (Table 1). Base temperatures were taken from Kronenberg (1988), temperature sums were calculated from other sources gathered for but not used in Kronenberg (1988).

'White Transparent' can be grown in Blangstedgaard and data of this station and of Belridge airport are used (Tables 2 and 3). To find the northern production limit of 'White Transparent', differences between reported data of flowering and picking and those calculated in 5 places were checked (Table 4). Similar information on 'Cox's Orange Pippin', 'Golden Delicious' and 'Granny Smith' is given in Tables 2, 3 and 4.

Table 1. Fruit growing locations and meteorological stations.

Place of apple observations	Meteorological station	Estimated distance between place of observation and meteorological station	Daily temperature is based on
Blangstedgaard (55° 40' north 10° 40' east) Denmark	Belridge airport Odense	5 km	(minimum + maximum): 2
Wilhelminadorp (51° 30' north 3° 46' east) Netherlands	Koninklijk Nederlands Meteorologisch Instituut Station Vlissingen	20 km	24 hourly observations

Table 2. Base temperatures and temperature sums for apple.

	April	May	June	July	August	Sept.	Oct.	Nov.
White Transparent (Blangstedgaard)								
Base temperature (°C)	0	18	18	2				
Temperature sum (°C days)								
1961		317	3	2	26			
1962		71	2	0	279			
1963		119	1	0	251			
1964		223	3	1	115			
1966		250	7	5	113			
mean		196	3	2	157			
Cox's Orange Pippin (Blangstedgaard)								
Base temperature (°C)	7	15	18	16	0	4		
Temperature sum (°C days)								
1960		52	24	4	24	336	0	
1961		83	29	5	7	409	0	
1962		6	11	0	2	363	81	
1963		42	16	2	27	367	0	
1964		80	17	4	18	322	0	
1965		0	6	0	4	407	84	
1966		63	38	10	8	359	0	
1970		13	70	8	22	340	0	
1971		98	18	18	35	328	0	
1972		61	16	32	24	295	0	
1973		82	41	28	34	260	0	
1976		41	42	31	48	368	0	
mean		52	27	12	21	346	14	
Golden Delicious (Blangstedgaard)								
Base temperature (°C)	8	16	20	14	14	0	0	
Temperature sum (°C days)								
1960		47	12	0	63	20	204	0
1961		56	16	1	29	33	341	0
1963		44	8	0	55	6	284	50
1964		70	9	0	48	12	224	0
1965		0	2	0	22	14	285	74
1966		39	23	2	34	16	280	0
1970		18	51	2	60	15	243	0
1971		81	10	2	75	5	246	
1972		50	9	12	57	3	220	0
1973		73	28	8	73	29	152	0
1974		71	11	0	63	27	193	0
1976		41	30	10	0	5	201	0
mean		49	17	3	56	15	244	10

Table 2. Continued.

	April	May	June	July	August	Sept.	Oct.	Nov.
Granny Smith (Wilhelminadorp)								
Base temperature (°C)	3	0	15	19	18	16	10	0
Temperature sum (°C days)								
1971	0	308	10	11	9	7	81	97
1972	0	306	3	9	2	0	32	0
1973	0	213	46	7	28	30	48	50
1974	27	362	18	0	6	3	2	31
1975	0	296	26	8	58	18	31	0
mean	5	297	21	7	21	12	39	36

Table 3. Parameters of the model for apple.

Period	Base temperature (°C)	T-sum (°C days)	Mean temperature (°C)	Length of period (days)
White Transparent				
1	0	196	–	–
2	–	–	14.5	30
3	–	–	16.2	30
4	2	157	–	–
Cox's Orange Pippin				
1	–	–	11.2	10
2	–	–	14.5	30
3	–	–	16.2	30
4	–	–	15.5	30
5	0	360	–	–
Golden Delicious				
1	–	–	11.2	10
2	–	–	14.5	30
3	–	–	16.2	30
4	–	–	15.5	30
5	–	–	12.5	30
6	0	254	–	–
Granny Smith				
1	0	302	–	–
2	–	–	16.4	30
3	–	–	18.5	30
4	–	–	18.1	30
5	–	–	15.9	30
6	–	–	11.5	30
7	0	36	–	–

Table 4. Checking for the four apple cultivars.

Place	Situation		Meteorological Station	Estimated distance (km) between place and meteorological station	Reported* mean or calculated (c)** flowering date	Reported* mean harvesting date	Calculated harvesting date by using the model	Difference between calculated and reported harvesting date
White Transparent								
Bordeaux	0°30'W	44°50'N	Bordeaux	<10	11/4	3/7	5/7	+ 2
Commentry	2°40'E	46°10'	Vicky	30	28/4	28/8	20/7	-39
Favesham	0°38'W	51°16'	Dungeness	40	2/5	6/9	10/8	+27
Wageningen	5°20'E	52°05'	De Bilt	40	8/5	29/7	30/7	+ 1
Wilhelminadorp	3°46'	51°30'	Vlissingen	20	9/5	24/7	1/8	+ 7
Cox Orange Pippin								
Bologna	11°22'E	44°30'N	Bologna	<10	14/4	27/8	19/8	- 8
Bordeaux	0°30'W	44°50'	Bordeaux	<10	15/4	21/9	22/9	+ 1
Commentry	2°40'E	46°10'	Vicky	30	30/4	30/9	7/9	-23
Sint Truiden	5°12'	50°49'	Beauvechain	30	30/4	12/9	1/9	-11
Ujfeherto	21°41'	47°56'	Debrecen	25	6/5	15/9	17/9	+ 2
Wilhelminadorp	3°46'	51°30'	Vlissingen	20	7/5	15/9	18/9	+ 3
Long Ashton	2°39'W	51°27'	Larkhill	30	8/5	4/10	22/9	-12
Faveshem	0°38'E	51°16'	Dungeness	40	8/5	23/9	22/9	- 1
Bavendorf	9°30'	47°45'	Friedrichshaven	<10	12/5	20/9	26/9	+ 6
Bonn	7°05'	50°45'	Bonn	<10	13/5	24/9	27/9	+ 3
Wageningen	5°20'	52°05'	De Bilt	40	16/5	21/9	29/9	+ 8
York	9°40'	53°30'	Hamburg	<10	18/5	26/9	5/10	+10
Golden Delicious								
Monte Bianco	7°10'W	38°50'N	Badajoz	25	3/4c	7-10/8	23/8	+16, +13
Lerida	0°38'	41°40'	Zaragoza	<10	8/4c	8/9	29/8	-11

Bologna	11°22'E	44°30'	Bologna	<10	14/4	17/9	4/9	−13
Bordeaux	0°30'W	44°50'	Bordeaux	<10	15/4	17/9	7/9	−10
Laimburg	11°45'E	46°30'	Trento	40	19/4	10/9	12/9	+ 2
South of France	5°55'	43°10'	Montpellier	20	20/4c	22/9	13/9	− 9
Commentry	2°40'	46°10'	Vicky	30	1/5	10/10	27/9	−13
Sint Truiden	5°12'	50°49'	Beauvechain	30	4/5	28/9	2/10	+ 4
Ujfeherto	21°41'	47°56'	Debrecen	25	7/5	22/9	4/10	+12
Favesham	0°38'	51°16'	Dungeness	40	8/5	23/10	7/10	−16
Wilhelminadorp	3°46'	51°30'	Vlissingen	20	8/5	8/10	5/10	− 3
Wageningen	5°20'	52°05'	De Bilt	40	9/5	16/10	8/10	− 8
Bavendorf	9°30'	47°45'	Friedrichshaven	<10	12/5	10/10	17/10	+ 7
Bonn	7°05'	50°45'	Bonn	<10	12/5	12/10	13/10	+ 1
York	9°40'	53°30'	Hamburg	<10	13/5	23/10	18/10	− 5
Granny Smith								
Monte Bianco	7°10'W	38°50'N	Badajoz	25	3/4c	7/9	27/9	+20
Bordeaux	0°30'	44°50'	Bordeaux	<10	12/4	7/11	8/10	−30
Bologna	11°22'E	44°30'	Bologna	<10	15/4	15/10	9/10	− 6
Commentry	2°40'	46°10'	Vicky	30	1/5	29/10	26/10	− 3
Wilhelminadorp	3°46'	51°30'	Vlissingen	20	6/5	29/10	31/10	+ 2
Ujfeherto	21°41'	47°56'	Debrecen	25	8/5	27/10	31/10	+ 2

* Reported: all sources are available from the author.
** Calculated: based on Kronenberg (1985a).

Table 5. Goodness of fit for the model used for four apple cultivars.

Cultivar	Added differences (days) (Table 4)		Frequency of differences	
			−	+
White Transparent	−39	+37	1	4
Cox's Orange Pippin	−54	+33	5	7
Golden Delicious	−88	+42	9	6
Granny Smith	+39	+26	3	3

Discussion of the model per cultivar

The lists of temperature sums given in Table 2 illustrate the irregularity of the West-European weather when studied per month.

In comparing the model for the cultivars (Table 3), there are similarities and differences. 'White Transparent' and 'Granny Smith' have a first period with a temperature sum. The last period has a temperature sum for all cultivars. The whole fixed period in between varies from 60-150 days, with the shortest period for 'White Transparent' and the longest for 'Granny Smith'.

The goodness of fit was checked by:
– the sum of the differences in days between reported and calculated harvesting date,
– the direction (– or +) of these differences (Table 5).
With differences being small and not 'one-sided', results for 'White Transparent', 'Golden Delicious' and 'Granny Smith' were acceptable. For 'Cox's Orange Pippin', this was achieved after introducing a 10-day period with 11.2 °C, instead of a base temperature of 7 °C and a temperature sum period.

For all four cultivars, on average a somewhat earlier picking date was found with the model. It is possible that this is introduced because the most northern location of reference was chosen.

Using the model

As a result of the foregoing, the northern production limits were estimated. For that, temperatures were taken from a number of places mentioned in Thran & Broekhuizen (1965); the moment of flowering was based on Kronenberg (1985a) (Table 6 for 'White Transparent'). Based on these results the lines of the map (Figure 2) were drawn.

The map shows that the four cultivars have different northern production limits. In West-Europe, lines come closer to each other than in the eastern part. The english climate has a long, not too cold season whereas in eastern Europe a shorter and warmer period for growing apples is found. There is a fair agreement between the lines in Figures 1 and 2.

In Norway, there is apple production north of the borderlines given in Figure 2.

Table 6. Using the model to analyse whether temperature regimes make ripening of 'White Transparent' apples possible.

| Place	Flowering date	Period 1 Base temp. 0 °C T-sum 196 °C days	End first period	Period 2 30 days Mean temp. 14.5 °C at least	Period 3 30 days Mean temp. 16.2 °C at least	End third period	Period 4 Base temp. 2 °C T-sum 157 °C days	Picking date	Qualification: production possible
Stavanger (Norway)	27/5	May temp. 8.8 °C		June temp. 12.1 °C too cold	July temp. 13.1 °C	–	Aug. temp. 14 °C	–	–
Lista (Norway)	26/5	May temp. 9.8 °C	10/6	June temp. 13.9 °C there are only 30 days warm enough	July temp. 15.8 °C	–	Aug. temp. 15.4 °C	–	–
Harstena (Sweden)	1/6		14/6	14.2 °C there are 60 days warm enough	16.7 °C	±	15.6 °C	±	±
Oslo (Norway)	28/5	10.5 °C	11/6	15.6 °C there are more than 60 days warm enough	17.3 °C	11/8	15.5 °C	23/8	+
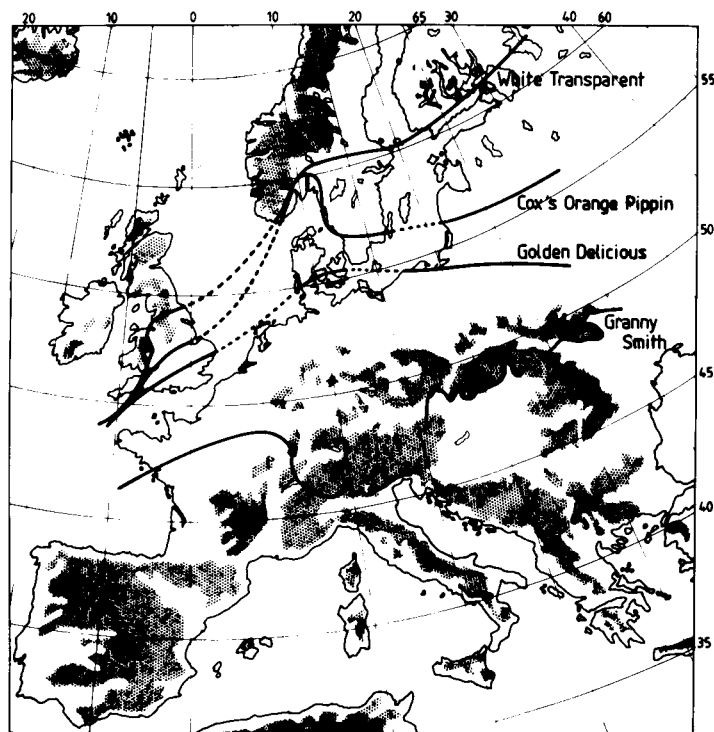
Fig. 2. Northern limit of production of four apple cultivars in Europe.

Cultivars used there may have lower temperature requirements than 'White Transparent', and micro-climatic conditions can favour production as for instance the terraced apple growing on the northern side of the Sognefjord. In England, apple growing shifts from commercial fruitfarms to private gardens above the lines.

The limits for production are seldom sharp and especially if prices are as high as, for instance, in Norway, production can be profitable even if ripening is not most excellent. The last phenomenon holds also for 'Granny Smith' at Wilhelminadorp, in the Netherlands.

Acknowledgements

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