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Apple growing potentials in Europe. 1. The fulfilment of the cold requirement of the apple tree[1]

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Summary

When 1000 hours below 7 °C are taken as measure for the cold requirement of the apple tree it is concluded that south of a certain line growing of most apple cultivars in Europe will give difficulties in most years. North of this line cold requirement was fulfilled the earlier in the season the farther north places were situated.

Introduction

The apple is the most important kind of fruit cultivated in the temperate climates of the world. This restriction to the temperate zone is due to the fact that the apple tree has a cold requirement for bud break in spring. The southern limits of apple growing (in the planes) in the northern hemisphere (and the northern limits in the southern hemisphere) are determined by these chilling requirements. Apple growing in the tropics is only possible above about 1000 m.

These requirements are considered fulfilled, i.e. the rest is considered to be completed, if leaves and shoots develop within 2 to 3 weeks after exposing the trees to temperatures suitable for growth. There are different methods to express the cold requirement. Usually the number of hours of temperature at or below 7 °C is used (literature surveyed by Giesberger, 1972). The system of chill units as introduced by Ashcroft et al. (1977) has not yet been developed far enough for apple to use for calculations as undertaken below. Giesberger states that apple trees need more than 1000 hours of 7 °C or less. If the number of hours of low temperature is less, delayed foliation results. F. Loreti (personal communication, Istituto di coltivazioni arboree, Pisa) reports that winter dormancy of Golden Delicious is overcome in Pisa at about 800 hours. So there are differences in chilling requirement between varieties. Loreti reports too that a few old

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varieties are giving problems in winters with 900-950 hours below 7 °C. In the calculations described below the 1000 hours below 7 °C are used, because this number seems to hold with most varieties.

System of calculation

Of the more than 600 weather stations in Europe used by Thran & Broekhuizen (1965) 131 situated lower than 100 m above sea level and well scattered over the area were chosen. Of each station hours of temperatures of 7 ° C or less were calculated as follows.

1. The average monthly minimum air temperature and the average monthly maximum air temperature were taken from Thran and Broekhuizen.
2. It was accepted that the daily temperature course was sinuous (sinesoide-shaped).
3. It was accepted that the average monthly temperature actually occurred on the 15th of any month. Between the 15th of one month and the next a linear progress was accepted.
4. In this manner it was possible to make air temperature graphs of every day. Only the part of the year with minimum temperatures lower than 7 °C was taken into consideration.
5. Numbers of hours with temperatures below 7 °C were thus found and added up.

Results and discussions

Tables 1 and 2 give the results of the calculations. Table 1 enumerates 12 places at which the 1000 hours below 7 °C are not reached, arranged according to the number of hours under 7 °C; Table 2 gives 119 places where 1000 hours below 7 °C are reached, arranged according to the dates on which this happens. Between the places mentioned in Table 1 and those of Table 2 a line on a map of Europe may be drawn connecting places with 1000 hours below 7 °C. Of the group of

Table 1. Number of hours with temperatures below 7 °C in 12 places in southern Europe.

Place	Number of hours
La Coruña	248
Brindisi	326
Pisa	329
Santander	337
Alghero	386
Athene	387
Porto Padres	382
Napoli	416
Barcelona	453
Ajaccio	721
Le Luc	872
Roma	998

Table 2. Dates on which the 1000 hours below 7 °C is reached in 119 places in Europe.

Place	Date (day/ month)	Place	Date (day/ month)	Place	Date (day/ month)
Marseille	12/3	Ambérien	22/1	Stettin	2/1
Perpignan	8/3	Chatillon	22/1	Halle	2/1
Split	3/3	Köln	22/1	Götenborg	1/1
		Constanta	22/1	Hamburg	1/1
Pescara	28/2	Odessa	22/1	Potsdam	1/1
Ancona	28/2	Bukarest	17/1		
Biarritz	28/2	Limoges	17/1	Biglandsfjord	30/12
Cherbourg	23/2	Edinburgh	15/1	Odense	30/12
Brawdey	21/2	Claremorris	15/1	Lärwick	29/12
Cognac	20/2	London	15/1	Multdorf	27/12
Dinard	19/2	Slåttersy	15/1	Warszawa	27/12
Brest	19/2	Stavanger	15/1	Karup	27/12
Valley	11/2	Eelde	15/1	Allenstein	26/12
Valentia observatory	11/2	Eindhoven	15/1	Kiev	26/12
Venezia	5/2	Trappes	15/1	Kironograd	25/12
Mount Batten	4/2	Praga	12/1	Brønnøsund	25/12
Carcassone	3/2	Stornoway	12/1	Jönköping	22/12
Stalin	2/2	Chaermont	12/1	Stockholm	22/12
Tiree	1/2	Skagen	12/1	Karlstad	22/12
		Karlsruhe	9/1	Riga	22/12
Toulouse	30/1	West Raynham	9/1	Tartin	22/12
Nantes	30/1	Wahnsdorf	8/1	Leningrad	22/12
Poitiers	30/1	Dublin	8/1	VelikieLuke	22/12
Bordeaux	30/1	Aberdeen	7/1	Kwisk	22/12
Felixstone	27/1	Oban	7/1	Zürich	22/12
Rennes	25/1	Bremen	7/1	Kråkenes fyr	22/12
Shannon	25/1	Trier	7/1	Uppsala	16/12
Beograd	24/1	Frankfurt a/M	7/1	Turku	16/12
Milano	24/1	Emden	7/1	Tampere	15/12
Cardiff	24/1	St. Etienne B	6/1	Gorky	14/12
Malin Head	22/1	Exeter	6/1	Donnarvet	10/12
Acklington	22/1	Hantsholm	6/1	Voshiy Voloshek	10/12
Blackpool	22/1	Bydgoszer	5/1	Vallersund	7/12
Spurn Head	22/1	Nancy	4/1	Smolensk	7/12
Pershore	22/1	Wick	4/1	Voronez	6/12
Dungeness	22/1	Kiel	4/1	Nyland	4/12
Den Helder	22/1	Friedrichshafen	3/1	Lillehammer	3/12
De Bilt	22/1	Freistadt	3/1	Kajaaini	2/12
Valkenburg	22/1	Osnabrück	3/1		
Zeebrugge	22/1	Caen	3/1	Gunnarn	17/11
Lille	22/1	Hela	2/1		
Duinkerken	22/1				

places in Table 2 only the first three are situated quite near such a line.

Fifteen places (12 south and 3 north of a line), however, is too small a number to construct a reliable line; therefore of all stations from Thran & Broekhuizen (1965) situated in the vacinity of the supposed 1000-hour line the same calculations as mentioned above were made. Fig. 1 gives the resulting line based on 49 stations. This line gives a good indication of the southern limit of apple growing potentials below 100 m – an indication because three facts have to be taken in consideration. First, meteorological stations are not always representatively situated for the surrounding area. Sometimes stations are situated in cities or on capes, which normally leads to higher minimum night temperatures or lower maximum day temperatures, respectively.

A second fact is that going uphill temperatures are lower with a drop in average temperature of 0.6 °C/100 m. Just a small rise of the land lowers temperature already somewhat.

The third fact is that cold requirement differs between apple cultivars. But moving just a little bit to the south in the Mediterranean area means a rather sharp rise in temperature (as shown in Table 1). The differences in cold requirement therefore do not move the line over a great distance. This pleads strongly

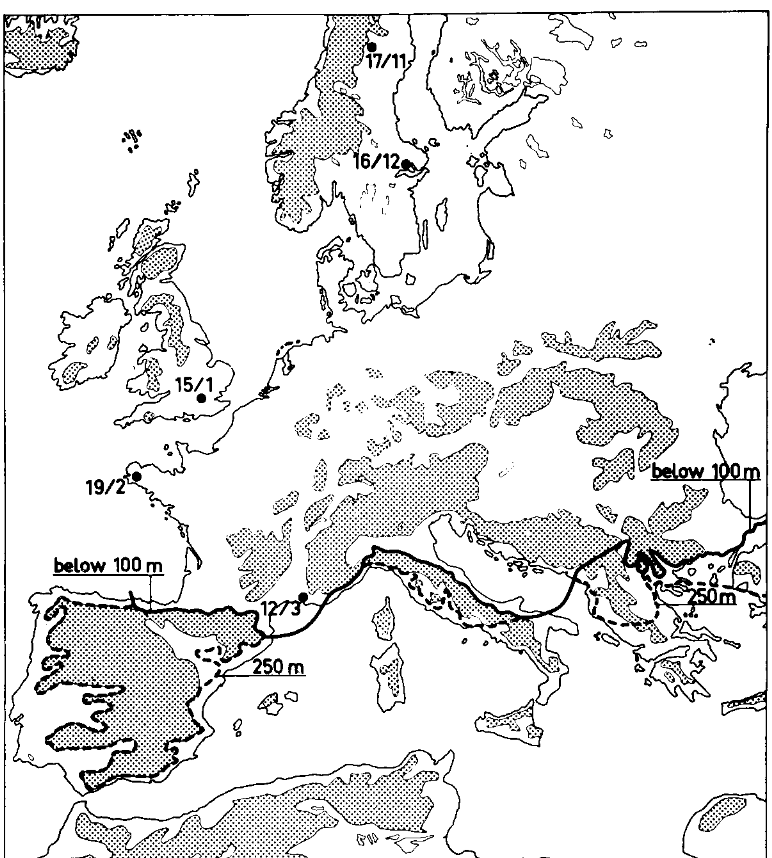

Fig. 1. 1000 hours below 7 °C line (below 100 m and on 250 m above sea level) and dates on which the 1000 hours below 7 °C is reached. Dotted areas: above 500 m.

in favour of rather a good validity of the line of Fig. 1.

Apple growing on a higher level, for example 250 m above sea level, will be possible south of the line drawn for apple growing below 100 m. To find the line delimiting this area the following system was used. Of all 55 stations used by Thran & Broekhuizen in the supposed area only two were situated on about 250 m (258 m); all others were between 18 and 865 m. Temperatures of these stations were adapted by addition or substraction (100 m $\sim$ 0.6 °C) to the 250 m level and the same calculations as mentioned above were made. Thus a '250 m above sea level 1000 hours below 7 °C' line was constructed. Taking the area above 250 m into consideration substantial parts of Spain, Italy and Greece are added to the area suitable for apple growing.

Table 2 gives information about the fulfilment of the cold requirement north of the lines. In Fig. 1 data are given of only 5 stations from Table 2 to illustrate the understandable fact that the nearer a place is situated to the 1000-hour line the later the cold requirement is fulfilled.

Literature about the dates of fulfilment of the cold requirements are scarce. Bibabé (1963) found the best apple blossoming forecast if he starts his calculations (on an average) on 20 January as the date on which dormancy is overcome. He used (mixed) data from experimental stations at Clermont Ferrand, Bordeaux and Angers. Table 2 gives data of Bordeaux (30/1) and of stations near Clermont Ferrand (St. Etienne 6/1, Limoges 17/1) and near Angers (Nantes 30/1, Rennes 25/1, Poitiers 30/1). Results of both calculation systems are in fair accordance with each other. The data from Table 2 are suitable to calculate or estimate average dates of apple blossoming as done by Sisler & Overholser (1943) with a temperature sums technique or by Bibabé (1963) with his Q 10 method.

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