2.2. Risk of frost

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Frost often causes damage to commercial plants. Plant damage occurs when low temperatures coincide with an early stage of plant growth. Thus late frosts in spring are particularly feared in Switzerland. Since 1951, the development time of certain plants starts earlier in spring on average by 11.6 days, whilst in autumn it lasts longer by 1.7 days. Parallel to this, the last day of frost in spring has occurred ever earlier at some measurement stations over the last 30 years. Though the risk of frost will continue to vary in future in relation to the change in climate, it is not possible to predict with certainty whether it will increase or decrease.

Introduction

In climatology, a frost day signifies a day with a minimum temperature below 0°C. In contrast, in biometeorology, which deals with the influence of the weather and the climate on living organisms, the term frost must be regarded in more detail. Thus in agro-meteorology, the term frost only applies when damage to commercial plants occurs. Since the resistance of plants to frost alters depending on their stage of growth, a minimum temperature below 0°C does not always signify a frost day. Frost therefore takes on a different meaning depending on the time of year. Frost is therefore defined in relationship to the time of year in which it occurs.

In Switzerland, *winter frosts* are of little significance, since indigenous plants are well adapted to the low temperatures. They can withstand temperatures down to –30°C without harm. By contrast, exotic commercial plants and decorative plants may suffer damage at less extreme temperatures in winter. In 1985 and 1987, some regions in Switzerland experienced damage to grapevines when the temperature sank below –20°C.

In Switzerland, *early frosts* in autumn present no great problem. Nonetheless, damage may occur to field crops if these are stored outdoors, and in horticulture.

Late frosts in spring are a cause of serious concern in Switzerland. For this reason, *MeteoSwiss* issues frost alarms in April and May. Late frosts can cause sizable damage in orchards, vineyards and in horticulture, since in spring, the plants are very sensitive at certain stages of growth (Fig. 23). Thus although closed flower buds can withstand temperatures down to –8°C, flowers in full bloom can only withstand temperatures slightly below the freezing point.

In assessing a frost event, the minimum temperature, the time of year and the length of the frost period all play a part. No simple definition of an extreme frost event is available. In the following, the agro-meteorological definition, which takes account of harm to commercial plants, will be used.

Meteorological conditions

Late frosts are divided into so-called advective frosts, transpiration frosts and radiation frosts. In Switzerland, the radiation and advective frosts are of main importance.

Advective frosts mainly occur with cold air masses coming from northerly to easterly directions. Thus they are primarily associated with the large-scale atmospheric circulation, and do

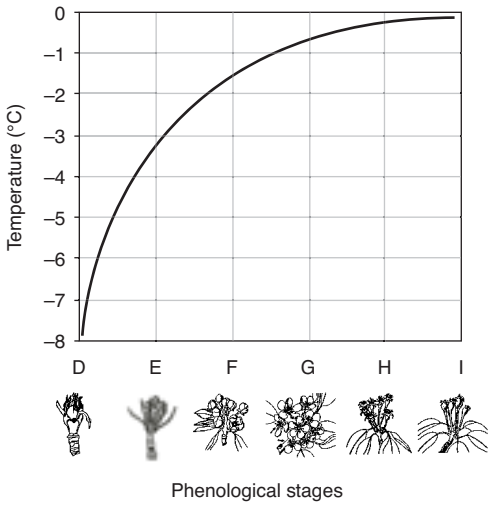

Fig. 23 Sensitivity of pears to frost at various phenological stages.

not depend on the time of day, and only to a small extent on cloud cover.

Radiation frosts occur when the radiation balance is negative, i.e. when the radiation from the ground or plants is greater than the incident radiation. This situation often occurs in spring in the early morning hours, and with a clear sky.[1]

Phenological trends

In Switzerland, surveys on seasonal plant growth and development have been carried out at yearly intervals since 1951. Additionally, a very long record starting in 1894 is available on the blossoming of cherry trees in Liestal (Fig. 24), and another beginning in 1808 on leaf sprouting of horse chestnut trees in Geneva.

A trend analysis of data in the interval 1951–1998 shows a time displacement and prolongation of the vegetation period. The changes are particularly conspicuous in spring, with leaf sprouting and full bloom occurring 11.6 days earlier. In autumn, the vegetation phases (leaf discoloration and leaf fall) show a small retardation of 1.7 days. There are, however, large regional differences.[2]

With an earlier start to the vegetation period, the risk of frost damage increases, since the number of frosts in March is higher on average than in May. Early awakening of the vegetation can lead farmers to commence earlier with sowing, increasing the likelihood of frost damage.

However, the higher risk of damage due to frost is compensated by the fact that over the last 30 years, the last day of frost has tended to occur earlier in the year at certain measurement stations. Thus in Zurich, the last day of frost now occurs on average about 10 days earlier than in 1975 (Fig. 25).

Influence of climate change

Climate change can affect frost events in several ways:

(a) *Increase in the minimum temperature*
The climate simulations available for the late 21st century display a tendency towards less frequent cold temperature extremes (see Chapter 2.1). Also, an increase in night temperatures was identified in the 20th century.[3] This could lead to a reduction of the frost risk.

(b) *Change in atmospheric circulation*
Climate change can influence the large-scale atmospheric circulation. Changed flow patterns in the atmosphere could lead to more – or to less – frequent advective frosts. The changes in circulation simulated by present-day climate models are still very contradictory, and at present allow neither quantitative nor qualitative conclusions to be drawn.

(c) *Changes in cloud cover*
Cloud constellations play a large part in the occurrence of late frosts. Nightime cooling of the atmosphere is less pronounced with a cloudy than with a clear sky. Should cloud

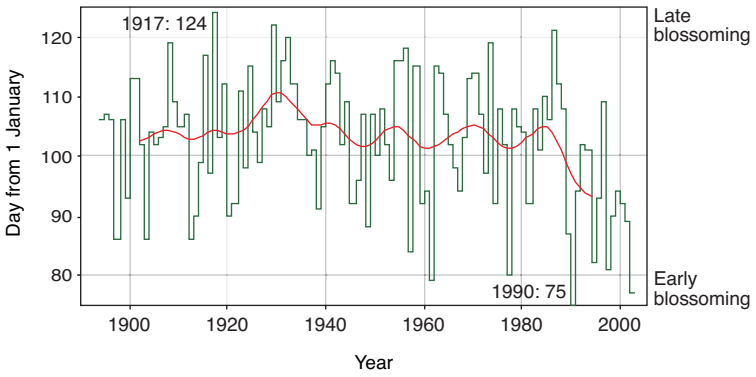

Fig. 24 Date of commencement of full bloom of cherry trees in Liestal 1894-2001. Since the beginning of the 1980s, cherry trees have tended to blossom ever earlier in the year. The vegetation period has shifted towards the spring.

cover increase as a result of higher temperatures and a higher rate of evaporation, the number of frost days could decline.

It is conceivable that the frost risk in Switzerland could alter as a result of climate change. Our knowledge on changes in large-scale circulation, cloud constellations and earlier vegetation growth permit nothing more than speculations. Current scientific knowledge allows neither an increase nor a decrease in the frost risk to be forecasted owing to the fact that two important parameters can change, i.e. the status of vegetation and the temperature. Furthermore, a single night with frost can heavily damage commercial plants. Even if the risk of frost days were to decline, individual frost episodes leading to plant damage could not be excluded.

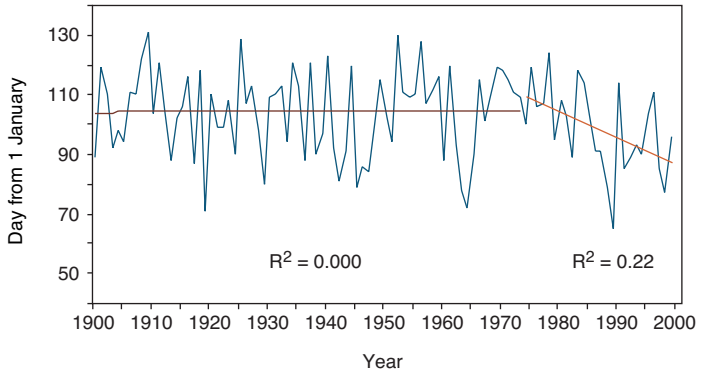

Fig. 25 At the measurement station in Zurich, the last day of frost has tended to occur ever earlier in the year since 1975. Not all Swiss stations display this tendency.

1 Brändli J., Das Frostrisiko im Frühling an ausgewählten Standorten in der Schweiz, 1961–1990, Klimatologie 1961–1990, 82 S., 1994.

2 Defila C. and B. Clot, Phytophenological trends in Switzerland, Int. Journal of Biometeorology, 45, 208–211, 2001.

3 Rebetez M., Changes in daily and nightly day-to-day temperature variability during the twentieth century for two stations in Switzerland, Theor. Appl. Climatol., 69, 13–21, 2001.