SOME CLIMATIC ASPECTS OF APPLE GROWING

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Abstract

Malus domestica Borkh is the most widely grown fruit in the temperate climate (worldwide only bananas and citrus fruits precede it). The regional impact of global warming has already been manifested in extreme weather events today. Signs of climate change are also reflected in the intensity and frequency of temperature and precipitation extremes. The number of heat waves and hot days will increase throughout Europe, including Hungary, which will be accompanied by the rarer extremes of cold and frosty days, which - supported by previous researches - may result in changes in apple production. The behavior of plants is influenced by various ecological processes, of which weather factors and climatic conditions are of great importance. Individual weather conditions, especially temperature, affect all aspects of apple growing.

Keywords: *Malus domestica*, global climate change

Összefoglalás

Az alma (*Malus domestica* Borkh) a mérsékelt égövben a legnagyobb mennyiségben termesztett gyümölcs (világviszonylatban csupán a banán és a citrusfélék előzik meg). A globális felmelegedés regionális hatása már napjainkban is megnyilvánult a szélsőséges időjárási eseményekben. A változó éghajlat jelei a hőmérsékleti- és csapadék szélsőségek intenzitásában és gyakoriságában is megmutatkoznak. Európa-szerte, köztük hazánkban is a hőhullámok és forró napok száma nőni fog, ami a hideg és fagyos napok szélsőségének ritkábbá válásával párosul, mely -eddigi kutatásokkal alátámasztva- változásokat eredményezhet az almatermesztésben. A növények viselkedését a különböző ökológiai folyamatok együttesen befolyásolják, mely hatások közül nagy jelentőségűek az időjárási tényezők és az éghajlati adottságok. Az egyes időjárási viszonyok, különösen a hőmérséklet, hatással van az almatermesztés valamennyi aspektusára.

Kulcsszavak: alma, globális klímaváltozás

Global climate change

One of the main topics of current climatological researches are the recognition of global climate change. Global trends in climate change indicate that global temperature has risen by about 0.4–0.8 °C on average in the 20th century (Panel on Reconciling Temperature Observations, 2000). As the environmental effects of this phenomenon are likely to be most pronounced in the proliferation of extreme weather events (primarily temperatures) rather than in changes in temperature mean, understanding the processes behind extremes may be important for both observation and analysis of their effects (Jones et al., 1999; Katz and Brown, 1992). The extent and frequency of global temperature extremes on a global scale - including the probability of heat waves - has been rising since the middle of the 20th century. According to forecasts, hot

extremes will become more frequent in most terrestrial areas, cold extremes may occur less frequently, and global average surface temperatures are also expected to rise (IPCC, 2014).
Changes in the concentrations of greenhouse gases and aerosols, as well as the transformation of the surface by humans and the development of incoming solar radiation, are changing the energy balance of the climate system. The increase in the greenhouse effect is arguably real and helps regulate the Earth's temperature. Without the natural greenhouse effect, the average temperature of Earth would be around -18 °C instead of the current 15 °C. In contrast, increased greenhouse gas emissions will cause further warming and long-term changes in all components of the climate system, increasing severe and irreversible environmental impacts (IPCC, 2014).
According to forecasts, changes in precipitation will not be uniform at regional as well as local levels, as while annual average precipitation is likely to increase at high and medium latitudes and in the Pacific equator, in many medium-latitude and subtropical arid areas, precipitation is expected to decrease. According to IPCC (2014), special weather events associated with precipitation will become more intense and frequent for the most part of the mid-latitude and rainy tropics.
The effects of climate change are most comprehensively experienced in natural systems. The increasing rate, magnitude of global warming and other changes in the climate system increase the risk of severe, comprehensive and sometimes irreversible adverse effects. Some risks affect only certain regions, while others should be taken into account in most parts of the world. Extreme warm temperatures affect phenology in many fruit species. The phenological phases are mainly determined by the genetic conditions, while the environmental factors influence the speed and rate of the processes. Numerous researches have been published to map the effects of weather events on the phenology of fruit trees in many parts of the world, including Europe (Legave, 2013), North America (Nemani et al., 2001), Asia (Sugiura et al., 2012) and the

southern hemisphere (Grab and Craparo, 2011). As described by these authors, each of the phenological changes was consistent with an increase in the number of days with extreme warm temperatures (Miraglia et al., 2009).

Fruit-bearing plants have a defined need for their environment at each stage of development (Soltész, 1997). Assessing the effects of climate change on fruit production allows researchers to predict changes in crop yields (Olesen et al., 2011), as climate change is expected to have a significant impact on global agricultural production (Slingo, 2009). Apple is a fruit species that is particularly exposed to the effects of climate change. Exposure to strong radiation or extremely high temperatures during the growing season can lead to a reduction in fruit production and a negative effect on certain content characteristics.

Malus domestica

Malus domestica Borkh is an important and popular temperate fruit, one of the oldest cultivated fruits (Morgan and Richards, 1993), native to many parts of Europe and Asia (Sandor, 2008). Apple prefers cooler climates (Lenti, 2011) and has a high ability to adaptation. It can generally be grown between latitudes of 25° and 52° (Ferree and Warrington, 2003), but under ideal environmental conditions it can be grown in other areas as well. High yield and good quality are expected at balanced temperature, free from extreme weather events.

Conditions of radiation

In case of apple, stressful conditions - such as strong solar radiation, high temperature and low relative humidity - subserve physiological disorders, such as sunburn (Schrader et al., 2001, 2003). Conditions of radiation also affect photosynthesis and fruit color. In terms of photosynthesis, the shading effect is significant. Leaves inside the canopy that receive only 50%

of the radiation reach only 25–30% of the assimilation compared to leaves exposed to direct sunlight (Avery, 1975).

The temperature of the fruit skin is generally higher than the air temperature, because fruits have very limited cooling capacity through transpiration. Sun damage, or sunburn symptoms on fruits range from white spots to dark brown, depending on variety and environmental conditions (Hernandez et al., 2014). Schrader et al. (2001) identified two main types of sunburn injuries. In the first case, sunburn necrosis results from heat death of the shell cells, as indicated by the breakdown of cell membranes. If the shell temperature reaches 52 °C in 10 minutes, necrosis develops. This temperature does not affect the integrity of cell membranes. Sunburn occurs when the surface of the fruit reaches 46-49 ºC, but the intensity of solar radiation also plays a decisive role in its formation. During sunburn tanning, the membranes of surface cells are less damaged. Furthermore, it has been found that UV-B radiation plays a higher role in the development of sunburn symptoms, than visible light. However, the side of apples exposed to sunlight has a high sun protection ability (Ma and Cheng, 2003). Natural defense mechanisms provide some protection against sun damage, such as epicular layer thickness and wax composition (Wünsche et al., 2004), accumulation of antioxidant compounds and sunscreen pigments (Felicetti and Schrader, 2009), all of them can affect sunburn. However, fruits are more sensitive to pathogen attack in the affected area (Racskó et al., 2005). Brooks and Fisher (1926) reported that sunburn injuries can occur if surface temperature of the fruit is 14 ºC higher than air temperature. In their view, damage to the surface can be caused by high temperature rather than sunlight.

Temperature, precipitation

Temperature has a high importance in apple growing in several ways. It determines, for example, the length of the growing season, the time and duration of phenological processes, and the occurrence of pests and diseases (Tóth, 2013). The preferred temperature range for apple is 15-33 °C. Moving away from the optimum (in the direction of both extreme hot and extreme cold temperatures), the speed of life processes decreases. When air temperature exceeds 35 °C, the degradation of organic matter from respiration exceeds the amount of organic matter formed during photosynthesis (Lakatos, 2004). The temperature of the orchard can be significantly higher than the temperature of the air. Thorpe (1974) studied an apple orchard on a cloudless day. The air temperature was 27 °C, the surface temperature of the apple exposed to sunlight was 13–14 °C, and the unexposed surfaces were 3 °C warmer than the air. As the number of days with extreme warm temperatures increases, the quality of apples will be damaged.

The growing season of apples lasts from bud burst to the end of foliage. The swelling of the buds starts at a mean daily temperature of 6 °C, if this temperature permanently exceeds it, the vegetative activity is undisturbed and the growth is continuous. The period from bud burst to flowering is closely related to temperature, this phase occurs between 6-18 °C. Above 9-10 °C the plant responds for a 1 °C temperature rise with a phase shift of 4-5 days, while it is only 1-2 days at 14-15 °C. The period between the beginning of flowering and petal death is 12-25 days, of which the flowering phase has a strong temperature dependence. The optimum temperature is between 9-24 °C. At around 10 °C, a 1 °C temperature change causes a 3-4 day phase change, while at 20 °C it is 1 day. The temperature varies between 16-24 °C in the period between the end of petal death and the time of ripening, and it is closely related to the length of the phase. At 17-18 °C, a temperature change of 1 °C results in a phase change of 10-11 days.

A temperature change of 1 °C at or above 20 °C causes a change in phase duration of 5-6 days (Lakatos, 2004).

Analyzes in the Netherlands also show that the rise in temperature and the acceleration of apple development are connected (Poldervaart, 2004), with a 1-2 days earlier trend in phenophases every decade.

Temperature greatly affects anthocyanin synthesis. In apple, high temperature prevents the accumulation of cyanide and UDP sugars (Ban et al., 2009), resulting in a rapid decrease in anthocyanins followed by renewable synthesis at cooler temperature and causing skin color fluctuations (Steyn et al., 2005). Lin-Wang et al. (2011) found that extremely high temperature decreases anthocyanin concentration in the apple skin.

In previous studies, Tukey (1959) found that temperature treatment of branches affected fruit growth. The controlled environment, for example, was set by Ford (1979) by exposing the trees to two opposite temperature systems for three weeks after flowering and showed that temperature strongly influenced the average fruit size. Later, in another study, Tromp (1997) showed that post-flowering temperature treatments significantly affected fruit ripening but had only a small effect on fruit weight at harvest. Bergh (1990) found that in addition to the defined relationship between temperature and fruit size, the timing of exposure to temperature is also significant.

Thus, apple is a deciduous species, it also needs a cold (dormant) period. The length of the frost-free period is of high importance for horticultural production (Anda and Kocsis, 2010). Research in recent decades has shown that the biggest problem was frost during flowering among the extreme weather effects, with frost damage causing much greater loss than all other environmental stressors combined (Tóth, 1982; Flore and Howell, 1987). Apple is sensitive to spring and autumn frosts. The critical value is -4 °C for apple buds, -2 °C for flowers and -1 °C for fruits. Autumn frosts can cause early foliage, fruit freezing and significant crop loss the following year (Caprio and Quamme, 1999; Lenti, 2011).

The lowest tolerated temperature for the fruit depends on the phenological condition. The extent of damage can be significantly influenced by the degree of cooling, the temperature of the winter period before spring frost damage and the development of the flowers (Zatykó, 1986).

Caprio and Quamme (1999) found that low yield averages are largely due to an increase in the frequency of temperature extremes.

Apple is a water-demanding fruit species, with a water demand of 600–800 mm. The half of it is required during the growing season (Tóth, 1997). Its water demand is the highest in summer, which can mostly be provided by irrigation.

Hungary

Hungary is located in the temperate zone. There is only a 3° latitude difference within the country, which cannot cause profound climatic differences between the southern and northern parts of the country, however, the orographic factors are not completely ineffective. Hungary is ranged to cool continental climate, which is suitable for the cultivation of apple, although extreme temperature changes are more common, and weather has a great variability (Péczely, 1998).

In terms of precipitation conditions, the change is significant from year to year, it ensures a water needs at medium level. Although most of the falling precipitation is concentrated in the summer period, in the case of apple growing irrigation may be necessary. There are significant differences between the annual rainfall of some of our landscapes. The west-southwest part of the country is one of the wettest areas, here precipitation is about twice higher (800-900 mm), than in the driest (lowland) districts (480-500 mm). Most rain falls in Hungary between May and July, which is suitable for apple production, as it requires the most precipitation during the growing season, but sudden, large amounts of precipitation can cause problems (on average 25-40 thunderstorm days occur in Hungary per year) (Péczely, 1998).

In the future, it is likely that the climate of the Carpathian Basin will become more droughty and weather extremes may become more frequent. According to experts studying the changes, as the climate becomes hotter and drier, there will be more and more negative effects in fruit production, both in terms of quantity and quality.

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