

Challenges – the impact of climate change on the nutritional management of Hungarian orchards

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Summary

The agricultural sector is increasingly exposed to both environmental and economic risks due to the phenomena of climate change and climate variability.

Fruit growth and productivity are adversely affected by nature's wrath in the form of various abiotic stress factors. Climate change and extreme climatic events are predicted to increase in intensity, frequency, and geographic extent as a consequence of global climate change. It is no doubt that frequency of unexpected climatic events and their growing rate result in an increasing amount of problems for fruit growers globally. Today, climate change impacts are the most serious problems for Hungarian fruit growers as well. It can be stated that the nutrient demand of fruit trees can be supplied only under even worse conditions.

Therefore, it is so important to know and apply adaptation and mitigation strategies in horticulture to improve fruit quality and yield. In the last ten years, at the Faculty of Agricultural and Food Sciences and Environmental Management at University of Debrecen expanded studies have been made to prove the importance of groundcover management in horticultural applications. In this mini review paper, is presented, how the university's researches contributed to the expansion of knowledge of preservation of soil moisture and what advice we can provide for fruit growers to face the challenges of climate change.

Keywords: climate change, climatic anomalies, nutrition, fruit, adaptation strategies

Introduction

Climatic influences have had effects on agricultural production for ancient ages. The mankind has always tried to adapt to the rapidly changing and sometimes hectic effects of weather which has very huge and important effect on the quality and quantity of crop production.

There are evidences of variations in climate, between years and regions which can have a strong effect on horticultural production worldwide. A warmer climate is supposed to be favourable for subtropical fruit production but at the same time can also be harmful for some temperate fruits (Luedeling, 2012; Kuden, 2013).

Climate change is likely to affect agricultural systems very differently in various parts of Europe. In northern areas, climate change may have primarily positive effects through increases in productivity and in the range of varieties grown, while in southern areas the disadvantages of climate change will predominate, with lower harvestable yields, higher yield variability, and a reduction in suitable areas for traditional crops.

Moreover, the extreme climatic events are predicted to increase in intensity, frequency, and geographic extent as a consequence of global climate change. It is no doubt that frequency of unexpected climatic events and their growing rate result more and more problems for fruit growers all over world. It is very hard task to estimate the fruit failure which follows from climatic extremes. But its rate is growing continuously year by year. Nowadays, we have to know the dark side of the weather events because it is causing more and more problems and significant hazards to many horticultural regions all over the world.

The quality of fruits is acquired during the development of the plant, for this reason it is necessary to know *in situ* the factors that influence in more or smaller degree in postharvest fruit quality. These are: the climatic factors (temperature, wind, rain, quality of air and solar light).

The increased risk of spring frost, new or more aggressive diseases and pests, hail and water shortage or more variable rainfall with longer droughts are some of the major factors highly detrimental for fruit crops (Chmielewski et al., 2004; Braun and Markus, 2012).

Of course, the physiological responses of plants to water stress and their relative importance for crop productivity vary with species, soil type, nutrients and climate. Physiological effects of climate change on photosynthesis, respiration, aqueous relations in cells and membrane stability during growth and development of fruit and vegetable crops have been documented (Collier et al., 2014). The elevated temperatures will also reduce or inhibit plant hormones, primary and secondary metabolites, and seed germination depending on the species and level of stress (Kuden, 2013). Colouring disorder, enhancement as well as reduction of fruit softening and spoiling acids have also been reported (Sugiura and Yokozawa, 2004). High temperature associated limited soil moistures are the key causes of low yields in vegetables in the tropics which will be aggravated day by day (de la Peña and Hughes, 2007).

Increasing temperature will reduced the irrigation water availability, decrease soil fertility, increase soil erosion and flooding and salinity incursion; which are major restrictive factors in sustainable fruit production (Wheeler and von Braun, 2013; Anwar et al., 2015). Moreover, changes in the timing of phenophases of fruit trees or field crops could be of great economic importance, because they could have direct impacts on yield formation processes and so on the final crop yield. In mid- and high

latitudes, with a vegetation-rest in winter (dormancy) and an active growing period in summer, plant phenology is mainly driven by temperature. After the release of dormancy the development of plants strongly depends on air temperature. With increasing temperature the biochemical reactions are accelerated up to a threshold where enzyme systems are destroyed and cells die (Chmielewski et al., 2004). Limiting resources, as stress factors during plant development have strong effects on fruit postharvest quality, mainly in terms of sensorial attributes (texture, colour, aroma, and taste) and composition (nutrients and bioactive compounds), and also in terms of gene expression, enzyme activity, yield, and storage behaviour because the stress situations reduce plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth promoters.

Certainly, most land plants are exposed to short or long term water stress at some times in their life cycle and have tended to develop some adaptive mechanisms for adapting to changing environmental conditions. But an earlier blossom of fruit trees holds the danger of damage by late frosts. Frosts before the beginning of blossom may cause masked injuries in flower buds, but the damage is less than it would be in the period of blossom. Frost during the flowering period can harm the blossoms, so that total crop failures can occur. The year 2007 and 2017 were good examples for the strong impact of late frost damages on apple yields in Hungary. The threat of late spring frosts, combined with more frequent mild winters, pose a challenge for even frost hardy species (Burroughs, 2002). Furthermore, the expected climate changes in this century will be probably much larger than those observed during the 20th century (Houghton et al., 2001).

Future climate change is projected to increase the length of the growing season. An increase in the length of the growing season, together with warmer climate during the growing season, may increase the potential for growing thermophilic fruits in open fields in lowland areas in Central Europe and increase the potential number of harvests (Bindi and Olesen, 2011).

Today, climate change impacts are one of the most serious problems for Hungarian fruit growers because Hungary has agro-ecosystems on more than 80% of its territory; therefore the agricultural sector's vulnerability to climate change is extremely high, and adaptation measures are very important. The climate of Hungary will likely shift to a more Mediterranean one with more frequent extreme events. For example, the year of 2007 and 2017 were particularly difficult time for Hungarian fruit growers, especially in Alföld region. Serious and repeated frosts occurred at blooming time in this region, which caused

almost 100% of fruit loss. Frost caused an “off-year” in the orchards. Another example was the April of 2018; it was the warmest April month over the past hundred years in Hungary. Despite of these facts, the Hungarian growers have a very little information about the effects of climatic change (Nagyné, 2009; Nagyné et al., 2010).

Considering our country, the effects of climatic factors on the fruit production zones can be evaluated upon the basis of the works of Soltész et al. (2004, 2005) and Nyéki et al. (2005). The main extreme climatic effects have been summarized by Soltész et al., (2010).

Especially, winter frost, spring frost, drought, sunburn, cracking and wind damage are regarded the most important climatic effects affected Hungarian plantations (Soltész et al., 2008). According to Soltész et al. (2004); it was evident that hotter temperatures can reduce yield in fruits by lowering photosynthesis, increasing respiration, and causing reproductive failure (split sets, flower drop, reduced seed set, reduced fruit set). Quality of fruits and vegetables can also suffer due to higher numbers of size and shape culls (reduced pollination), increased internal defects (heat necrosis), and increased tissue damage (sunburn and sunscald).

Results and discussion

Climatic effects on nutrient uptake of fruit trees

Besides on the applied technological elements, like irrigation, nutrition, plant protection, etc. the climate has a great influence on nutrient uptake of fruit trees. In fruit trees, one can consider a number of possible threats to production associated with climate change. These could be the increased risk of spring frost, increased risks due to new or more aggressive diseases and pests, hail and water shortage due to drier summers or more variable rainfall with longer droughts.

For example, reduction in photosynthetic activity and increases in leaf senescence are symptomatic of water stress and adversely affect crop growth. Other effects of water stress include a reduction in nutrient uptake, reduced cell growth and enlargement, leaf expansion, assimilation, translocation and transpiration. Water and nutrient availability is one of suboptimal phenomenon like most of the natural environments occur continuously, with respect to one or more environmental parameters (Akıncı and Lösel, 2012).

The nutrient uptake of crop plants greatly influenced by including overuse of the land in agricultural activities, climate change, precipitation regimes, root morphology, soil properties, quantity and quality of fertilizers, amount of irrigation. The root structures such as root extension rate and length, the means of root radius and root hair density

affect the quantity of nutrient uptake by a tree. However, the spreading of using of dwarf and semi dwarf rootstock results a higher sensitivity for drought because of the shallower root zone especially when the soil type is sandy.

Nutrient elements availability plays vital role for plant growth, nevertheless these physiological factors in nutrient, in soil, in plant or at the root absorption sites may interact as well as antagonistically and synergistically of the plants.

Many nutrient elements are actively taken up by plants, however the capacity of plant roots to absorb water and nutrients generally decreases in water stressed plants. It is rather difficult to identify the effects of water stress on mineral uptake and accumulation in plant organs. Most studies have reported that mineral uptake can decrease when water stress intensity is increased (Akıncı and Lösel, 2012).

Combating climate change impacts: adaptation and mitigation strategies

Nowadays, the strong trends in climate change already evident, the likelihood of further changes occurring, and the increasing scale of potential climate impacts give urgency to addressing agricultural adaptation more coherently.

It is no doubt that climate change is a reality and the pressure over water reserves will increase in next years, as well over high water consuming activities. Agricultural practices are among the biggest water consuming activities, considering that, alternatives to reduce water use in agricultural practices is of special interest in the present moment.

Nowadays, in Hungary, many growers in some regions will need to adapt their orchards to cope with days of extreme climatic event, including frost in spring, drought in summer and water deficiency in autumn.

Therefore the climate conditions and the proper orchard management practises are the main key factors in the production of high and qualitative yields of fruits (Bramlage, 1993).

In general, to grow crops, especially fruits successfully in the future, growers will need to adapt to the limited resources and the tested technologies of fruit growing according to these climatic events as modifier factors (Nagy et al., 2010).

Adaptation strategies in Hungarian fruit growing sector

To avoid the negative effects of climate change in horticulture for the fruit growers the following strategies are recommended:

- *Water preserving soil management* (mulching) that may contribute to storage of higher amounts of annual precipitation;

- *Increment of irrigation – Efficient irrigation measures* – Various technological improvements in irrigation practices such as drip and sprinkle irrigation are important to reduce the water loss and to maintain soil moisture as needed by some specific crops. Irrigation of fruit trees not only provides some security in protecting a large investment with potentially high returns against droughts, but serves also to increase and stabilize production. In addition, it has been shown that proper irrigation practices can have a positive influence on the quality of the harvested produce and any resulting processed product.
- *Breeding and use of drought tolerant fruit varieties* - selection for high yield in stress-free conditions has, to a certain extent, indirectly improved yield in many water-limiting conditions. Further progress requires the introduction of traits that reduce the gap between yield potential and actual yield in drought-prone environments;
- *Improved forecasting of weather* and related phenomena and easy access of these to local farmers;
- *Shifting and adjusting the timing of different farm operations* and cultivation practices to correspond the changing weather conditions;
- *Research and development* - Introducing genetically engineered drought and flood resistant crop varieties and high yielding varieties for low production areas to adapt with the climatic aberrations in different regions of the world

As growers face the challenges of climate change, there are a number of tools or strategies that can be used to mitigate the effect of higher temperatures or other climatic effect.

For example, radiation blocks or reflective materials can reduce heat effects by reflecting away some solar radiation. Commonly, particle films are used as radiation blocks including kaolin (white clay) based or calcium carbonate (lime) based materials. These are sprayed on plants during high temperature periods. Particle films are commonly used to reduce sunburn in watermelons in southern regions. Wax based reflective materials have also been used in fruits such as apples to maintain colour (Racskó and Schrader, 2012).

Shading is another strategy. Commonly, shade cloth or netting is used for this purpose. This netting comes in black, green, white, and reflective aluminium colours and is commonly used at the 20–30% shade levels. Shading is applied during the hottest periods or periods when the plant is most sensitive to heat.

Metabolic and developmental regulators may also have a place in stress mitigation. These are chemicals that are applied to plants and reduce stress through different mechanisms. Ethylene inhibitors such as 1-methylcyclopropene (1-MCP) when applied during the pre-harvest

period, 1-MCP has the useful effects of delaying fruit drop, slowing fruit maturation and ripening, and maintaining postharvest quality (McArtney et al., 2008; Watkins, 2010; Watkins et al., 2010). Hormones such as cytokinins and jasmonates alter different biochemical pathways related to plant stress. Flower or fruit initiating hormones (auxins, gibberellins, cytokinins and combinations) can improve flower and fruit set. Unfortunately, we have few labels for use of these products in fruit crops.

Water-based cooling can be employed to reduce heat loading in crops and crop environments. Evaporative cooling has been commonly used in greenhouses to cool air entering houses and reduce temperatures for greenhouse grown vegetables. Fogs and humidors have also been employed for this purpose. In the field, low water volume sprinklers, either continuous or pulsed, have been successfully used during hot daytime periods for plant cooling. Irrigation timing can also be used to as a tool. For example, by starting drip irrigation soon after dawn, soil under black plastic mulch will remain cooler for longer periods during the day.

Some biological root inoculants have also been shown to reduce plant stress. Mycorrhizal fungi can act as root system enhancers, increasing the effective area for absorbing water from the soil. *Bacillus subtilis* bacteria for root inoculation that has been shown to improve plant stress tolerance (Hayat et al., 2010).

While stress mitigation tools may be more commonly used in fruits as the climate warms, adaptive changes should be considered for more long-term stress management. One adaptive change would be to switch to crops that are more heat tolerant for summer production.

The volume of this paper is unfortunately too short to detail the all above mentioned effects, therefore here only the mulching technique is on focus.

Agriculture is facing increasingly frequent periods of drought, and in the future water reduction is expected to exert the most adverse impact upon growth and productivity among abiotic stress factors (Shao et al., 2008). This trend is of particular concern in Hungary, which will experience more frequent periods of intensive drought, leading to the extension of arid areas. Therefore, the importance of the irrigation and water preserving soil management will be increased in the near future.

In the last ten years, at the Faculty of Agricultural and Food Sciences and Environmental Management at University of Debrecen expanded studies have been made to prove the importance of groundcover management in horticultural applications (Nagy et al., 2006, 2009, 2011, 2013). Ground covering experiments were set up in peach, apple and

pear plantations among different site conditions to study the effects of ground cover materials on soil properties, nutrient uptake by trees and fruit quality. More details about the experiment designs and results can be found in these publications.

The importance of ground covering technique

The preservation of soil moisture might be a solution for the moderation of the effects of inadequate water-supply. The importance of ground management has increased in fruit growing sector in the last few decades owing to its application in organic farming (Skroch and Shribbs, 1986) and as it is regarded as excellent water saving method (Merwin et al., 1994), and for profitable and sustainable tree fruit production (Geldart, 1994; Derr, 2001). The importance of mulching is intensified by the decrease of available soil moisture and frequent drought events.

Mulching has several benefits which were summarized by Merwin et al. (1994). Mulches are not only highly effective in checking evaporation and weed control, but also have influences on several processes in the soil. The benefits are variously attributed to the suppression of weed growth, to the conservation of moisture by reducing evaporation and run off, to protection from erosion, to increased infiltration of water, to the increase or decrease of soil-temperature fluctuations, to the enhancement of mineral nutrient availability, to the enhancement of nitrification, to additional nutrients and organic matter derived from a decomposing mulch, or to the preservation or improvement of soil structure (Johnson and Samuelson, 1990; Stevenson and Neilsen, 1990). Moreover, mulching has a positive effect on nutritional and biological factors as well.

On the one hand, mulching causes an increase in the nutrient content of the soil as water leaches nutrients out of the mulch. However, the entire condition of nutrient availability may be modified for better or worse by changes induced in the moisture and temperature regimes of the soil. On the other hand, applying mulches increases root length density and brings the roots closer to the surface (Merwin and Stiles, 1994). Moreover, mulching enhances apple fruit storage quality (Lang et al., 2001).

Several publications pointed out that mulching has a positive effect on the water and temperature regimes of soil and it involves nutritional and biological factors as well (Mäge 1982; Skroch and Shribbs, 1986; Parker and Hull, 1993; Merwin and Stiles, 1994; Nielsen et al., 2003, 2004; Yin et al., 2007).

Nowadays the number of irregular climatic anomalies is growing due to the global climatic change. It is very important that the productivity and the available nutrient supply of soil should be improved under these climatic conditions.

Based on the study of Merwin et al. (1994) and Merwin and Stiles (1994) mulching seems as an effective tool to achieve the above mentioned goals mostly in organic production systems where the possible nutritional tools are restricted and the consumer demands are high.

Conclusions

In this section will be presented, how the university's researches contributed to the expansion of knowledge of preservation of soil moisture and what advice we can provide for fruit growers to face the challenges of climate change.

From the results of the carried out experiments, the following conclusions can be stated:

- Our results pointed out that the treatments had no effect on seasonal changes of soil temperature but affected the degree of fluctuation of soil temperature. The fluctuation of soil temperature was more moderate at the usage of mulch and manure.
- Results of chemical analysis of leaves showed that the leaf N, K and Ca concentrations increased but leaf Mg and Zn decreased by the treatments. Leaf Mn and Cu content were slightly affected by the treatments and the changing was inconsistent sometimes.
- Overall, our results suggest that leaf nutrient concentrations respond differentially to different mulches, and the responses vary with growing season.
- Our results suggest that the cover management offers possibility to correct and improve the existing disharmonious nutrient ratios.
- Obtained results indicate that groundcover management is a useful tool for satisfying the demand of trees because it improves the availability of nutrients, reduces weed competition, results moderate fluctuation of soil temperature and causes balanced nutrient ratios in leaves. After preliminary results we needed further investigation to determine the optimal rate and form of mulch needed in order to produce a more sustainable production system (Nagy et al., 2011).
- Our results pointed out that used ground covering matters divided into more categories regarding their effects.
- Available N, P and K content of soil was mostly increased by applying manures.
- Effectiveness of straw, mulch and mostly black foil was more lower than using different manures.
- Differences were found between nutrient supplying treatments and those treatments which did not supply nutrients (Nagy et al., 2009).

Acknowledgements

Special thanks to József Nyéki, Miklós Soltész and Zoltán Szabó for technical supports.

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