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The effect of climatic anomalies ont he nutrient supply of fruit plantations (Minireview)

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Summary: Climatic conditions play an important role in agricultural production. It has a profound influence on the growth, development and yields of a crop, incidence of pests and diseases, water needs and fertilizer requirements in terms of differences in nutrient mobilization due to water stresses. 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 in Hungary. The aim of this study is to explore the problems of nutrient uptake following climatic anomalies and response. These problems are: (i) water supply problems (water-stress); (ii) drought and frost as temperature-strees.Reviewing the effects and nutrient disorders caused by climatic anomalies, the following statements can be taken:

- Nutrient demand of trees can be supplied only under even worse conditions.
- The most effective weapon against damage of climatic anomalies is preventative action.
- When developing a fruit orchard, three factors should be taken into consideration: "Location, Location, Location".
- Moreover, proper choice of cultivars, species and cultivation should provide further possibilities to avoid and moderate the effects of climatic anomalies.
- Fruit growing technologies especially nutrition should be corrected and adjusted to the climatic events as modifier factors.
- Urgent task of the near future is to correct and adjust the tested technologies of fruit growing according to these climatic events as modifier factors.

Optimal nutrient supply of trees decreases the sensitivity for unexpected climatic events. To solve these problems supplementary, foliar fertilization is recommended, which adjusted to phonological phases of trees.

Another solving is groundcover of soil means a potential opportunity to temper or even avoid climatic anomalies.

Key words: climate, nutrient supply, fruit

Introduction

Climatic anomalies are significant hazards to many horticultural and viticultural regions in Hungary. Theoretically, any crop can be protected from any climatic event, but economic and practical aspects limit the methods that can be used. Profitability ultimately determines whether the protection techniques can be used. An understanding and ability to minimise the risk of fruit loss or damage is fundamental to managing a profitable enterprise. Damage not only puts at risk the current season's crop, but also because of the perennial nature of fruits and grapevines, can influence the productivity of fruits and vines for several seasons in the future.

It is no doubt that frequency of unexpected climatic events and their growing rate are resulting 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. Change of climatic conditions cause new tasks for today's fruit growers and scientists as well. Urgent task of the near future is to correct and adjust the tested technologies of fruit growing according to these climatic events as modifier factors. It is peculiarly true for nutritional aspects of fruit growing technology which respond sensitively for changing of environmental conditions. The aim of this study is to explore the problems of nutrient uptake following climatic anomalies and response.

Disturbances in nutrient uptake caused by climatic anomalies

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).

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)*.

Problems in water supply

Water supply problems in nutrient-uptake of fruit trees, like too high or even too low amount of plant-available water-content of soils, affect significantly the quality and quantity of yield. This statement is especially valid for Hungary, because our fruit-production depends highly on the available water-amount and on its favourable distribution during the vegetation period. In the last 50 years the amount of precipitation has demonstrably reduced and its distribution has become even more unfavourable (*Lakatos et al., 2005b*). Regarding the amount of precipitation per each time even extremer values turn up, while sweltering heat periods occur even more often and even longer. As a result of all these factors, soil drought is getting more abundant and the ground water level is sinking on even more sites (*Soltész et al., 2004; Nyéki et al., 2005; Soltész et al., 2005*). Summarizing all these, it can be stated, that the water demand of fruit trees can be supplied only under even worse conditions. So irrigation plays a very important role in secure fruit production.

In the past few years, water supply problems – that are summarized in the international literature as the term of "water-stress" – have become the focal point of numerous publications. Fruit plantations, just like every plant have a physiological reaction to the anomalies in water supply.

Stress reduces both water and turgor potential in fruits but stressed plants try to maintain turgor potential by osmotic adjustment. Water stress affects the turgidity pressure and osmotic potential of cells, therefore their water-uptake (*Ranney et al., 1991*).

The reduction in leaf water potential induces stomatal closure and increases abscisic acid levels in the leaves (*Shackel et al., 1990*). Stomatal closure leads to reduced photosynthesis, carbon-assimilation and transpiration, while severe stress can also affect the photochemical and enzymic reactions of photosynthesis. Shoot growth is more sensitive to water stress than crop yield. In stressed plants yield losses can be caused by reductions in inflorescence initiation, fruit set and fruit size as well as by increased fruit abscission. Yield losses are greater when stress occurs prior to the ripening stage of fruit development than during ripening. Mild stress during the ripening stage hastens the maturation processes in fruits and this leads to increases in the concentration of sugars and anthocyanin pigments and decreases in acid and pH levels in the fruit. Some major gaps in our knowledge of the subject of water stress are what effects stress has on respiration, translocation, hormones, mineral nutrition, physiological activity of roots, root growth and fruit quality (*Nagarajah, 1989; Holb, 2004*).

The decrease of water state – hydrature – of plant tissues infers partway also the dehydratation of cytoplasm. For the cytoplasm contains most of the enzymes of plant metabolism, firstly their function will be reduced. The decreased hydrature brings often respiratory problems, enhances the protein and starch-decomposition (because of the enhanced amylase activity).

The growth of the shoot is also blocked because of the small turgidity. As an effect of water stress, the default of blooming, fructification and fruit growth, just as the unfavourable ion-uptake result in the failure of the yield. This fall-out is even more expressed, if the stress comes up before, than during the ripening period. A slight ripening stress accelerates ripening procedures, therefore it increases the amount of saccharides and anthocyanine-pygments and decreases the acid-concentration of fruits.

Water stress substantially reduced fruit size and yield but had no effect on these fruit quality attributes. Water stress increased only K and B but fruit Ca was unaffected by any treatment. Mean dry weight of dormant spur flower buds was reduced by water stress. (Guak et al., 2001)

Unfortunately our knowledge on the effect of water-stress on the respiratory, translocation, hormonal and nutrient-supply procedures – that are closely related to the development of fruit quality – are still quite incomplete.

The effects and intensity of water-supply problems highly depend on the soil of the production site. On the sandy loam site, reduced fruit fresh weight occurred within four weeks after the imposition of water stress. Similar diameter reductions were not measured on the silt loam until five weeks after water stress initiation. Moreover, both water stress treatment and soil type affected fruit diameter and fruit weight. The seasonal pattern of fruit N, P, K, Ca and Mg concentration were unaffected by the water stress treatments and soil type, decreasing from maximum early in the season, to minimum at harvest. The accumulation of Ca per fruit increased continuously throughout the growing season, peaking two weeks prior to harvest, and then declining at harvest. This pattern was unaffected by water stress or soil type. The accumulation of N, P, K, Mg was continuous throughout the season, usually reaching a peak at harvest and sometimes was reduced for the water stressed apple trees grown on the sandy soil. (Yao et al., 2001)

Interestingly they came to the statement, that neither water-stress, nor soil type affect the uptake and uptake-dynamics of N-, P-, K-, Ca- and Mg-ions.

There are relative few literature-data about the other type of water-supply problems: the high amount of precipitation that falls suddenly and causes anomalies in nutrient-supply. The even frequent occurrence of this phenomenon in Hungary as well suggests, that it's reasonable to investigate and introduce its effects on the nutrient-supply. The high – sometimes either one-month – dosage of precipitation that falls awhile affects significantly the circumstances of nutrient-uptake in the soil. This is mainly determined by the soil type. Soils with higher clay- or loam-content and higher plasticity retain more water, than sandy soils. In case of these clay and loamy soils, water-surplus or even stagnating water state may occur periodically because of the relief and/or soil texture properties.

Water-surplus has a negative effect on the oxidation-reduction processes of soils and on root respiration. The reductive circumstances in the soil induce many processes that affect the nutrient-uptake. Through the reduction transformation processes and leaching the amount of plant-available nutrient-forms decrease. Mineralization processes and root-respiration also fall back and lead to the inhibition of nutrient-uptake. Nut sufficient nutrient-uptake may cause symptoms mentioned above. If the ground water limit lies above 150–180 cm, or 200 cm under ground level, it means for arboreal species in Hungary a limiting soil parameter for fruit plantation.

The negative change of aerating conditions in the soil affects the root development as well. High amount of suddenly falling precipitation, too high level of ground water limit or the compression caused by cultivating machines lead to even longer water saturation state and reductive circumstances in the soil that bring root necrosis or – not very typically – shallow rooted plants on. Finally these mean a danger to tree-stability, and life-span of trees. The results of *Papp and Tamási (1979)* pointed out, that on a sandy soil with too high ground water level 75 % of the root of four year old cv. 'Jonathan' apple trees on M4 rootstock lied shallow, in the upper 30 cm layer. In case of a higher yield-amount, it would cause problems in stability and nutrient-uptake.

Problems, mentioned above can be corrected by appropriate tillage, so the unfavourable soil parameters can be done away.

Versions for solution

It is still a matter, whether these effects and stresses can be avoided or corrected, and if yes, how much and by which nutrient-supply method.

It can generally be stated, that plantations with adequate nutrient-supply and of good condition are more tolerant to stress. Not appropriate water-supply – both drought and surplus – results in decreasing nutrient supply, therefore in blocked growth and fruit increment.

Not adequate water-supply, drought or even too wet circumstances affect also blooming and fruitset. Soil drought or even abundant water-supply of soil decreases the efficiency of nutrient-uptake via roots. The migration of nutrients to the radicles by diffusion or mass-flow is quite hindered in dry soils. Under unfavourable, e.g. dry soil conditions nutrient-supply is more hindered on heavy soils, than on light sandy soils. In case of persistent drought Fe-, Mn- and K-deficiency on heavy soils is related to this fact.

The nutrient providing potential of soil is determined by not only the nutrient-amount, but by the soil properties, like soil texture, humus-content, permeability, soil temperature etc. In case of the not appropriate water-supply and due to that the decreased nutrient-uptake potential foliar fertilization – as a complementary nutrient-supply method – plays a very important role.

Rufat and Arbonés (2006) are found that foliar treatments are more effective under dry conditions due to the low root absorption rates from dry soils. The water-deficiency and the adequate water-supply affects mainly the N- and K-uptake – as *Fallahi et al. (2006)* stated.

Besides foliar fertilization the preservation and supplement of soil moisture might be a solution for the moderation of the effects of inadequate water-supply. In the last few decades it is getting even more common used covering or mulching soil surface. Although mulching technology is as old as agriculture itself (*Libik – Wojtaszek, 1973*), it got common used only in the past decades, with the spread of ecological farming (*Skroch – Shibbs, 1986*).

Not only evaporation and weeds are suppressed by mulching, but it affects many processes in the soil as well. It plays an important role in the preservation of soil moisture, decreases the possibility of leaching (e.g. in case of heavy and suddenly falling precipitation), defends erosion, reduces the fluctuation of soil temperature, increases the availability of nutrients, enhances the nitrification and humus formation, and improves soil texture (*Nagy et al., 2006*).

In addition soil coverage has a positive effect on some biological aspects of soil vitality, on the density, development, growth and location of roots, beside these it slightly provides nutrients (*Merwin – Stiles, 1994*).

These effects of soil coverage mean a potential opportunity to temper or even avoid climatic anomalies.

The supplement of soil moisture is the other emphasized method. It is almost out of question nowadays to grow fruits up-to-date and quality oriented without irrigation and the application of irrigation systems. *Soltész et al. (2005)* points out, that in the region of the Hungarian Great Plain it is a burning problem to bring irrigation into effect.

The volume of this paper is unfortunately too short to detail all the effects of irrigation on the yield and its quality, therefore we only mention the most important current relations.

Due to the shrinkage and the fail of the quality of subsurface water it is even more reasonable to use surface water-based irrigation (*Soltész et al., 2005*). It is inevitable to adopt water-sparing, but efficient irrigation-systems in the near future. The introduction of fertigation – that is already common used in West-Europe and in America – is expectant in Hungary; still its technical background is adopted on even more plantations. We shouldn't forget that fertigation and irrigation basically affects the condition nutrition-physiologic aspects of plantations. The use of not appropriate water quality may lead to cumulating soil acidity, increment of saline-content and unbalanced nutrient-uptake. The application time, and the rationalized dosages of fertigation mean basic criteria for ordinaire fruit production.

Nielsen et al (2004) also have pointed out the relationships between water regime and N-uptake in their fertigation experiment. Leaf and fruit N increased linearly as N concentration of sprinkler-fertigating solution increased from low to high values. Optimum yield and highest fruit quality were associated with the medium N treatment. Sprinkler fertigation of P and K did not increase leaf and fruit concentration of either nutrient or meaningfully affect tree performance.

Dolega and Link (1998) also came to similar results: they didn't found any significant relationship between fertigation and fruit hardy, acidity, sugar-content, or the amount and rate of nutrients in the fruit.

Malaguti et al. (2006) found in their fertigation experiment, that the K-content of plants and soil increased as well and that fertigation affected the fruit-coloration also positive, but there couldn't be revealed any similar effect in case of P, Mg, N and the chlorophyll-content of leaves.

They also emphasized that by fertigation a better and to the phenological phase of plants more appropriate nutrient-supply practise can be achieved. We would like to add that disturbances in nutrient-supply caused by periodic climatic anomalies can be mitigated and their effects moderated using this technology.

Although fertigation is an approved and even more common-used environment-friendly nutrient-supply method, *Hornig and Bünemann (1995)* realized on a newly set 'Elstar'/M9 plantation that by fertigation there are still many nutrient-supply problems to be cleared.

The effects of temperature

The basic role of temperature factors is important from the aspect of nutrient-uptake and nutrient-supply. Both too high and too low temperature values actuate many harmful physiological processes, that affect nutrient-uptake and hereby the amount and quality of yield.

Regarding the number and extent of frost damages in the winter and spring time as well, the grade and frequency of low temperature values during the vegetation period has risen in the past 50 years (*Lakatos et al., 2005a; Lakatos et al., 2005b*).

Temperature values have major roles on two points in plant nutrition: on the one hand air temperature, on the other hand the therefore developing soil temperature values affect plant nutrition.

Although in many physiological aspects plants react to air and soil temperature values in similar way, their separate discussion is reasonable to clear the differences between their effects.

Soil temperature

The roots of different fruits have different demand on temperature. It follows that in case of different rootstocks and genera root growth doesn't start and stop at the same time (*Tamási, 1979*).

The undisturbed phenological processes (nutrient-uptake, the constitution of plant organs, blooming and shoot-growth) are closely related to soil temperature values.

On fields soil temperature of fruit-plants is determined by many factors: the inclination and the exposure of the site, soil moisture, soil composition (humus-content, amount and quality of clay minerals, etc.), stratification and structure circumstances, temperature reflexion of soil, specific heat and heat conduction of surface material.

Roots of fruit plantations start growing by 5–7 °C (in *Terts's (1970)* opinion by 7–8 °C), depending on the soil stratification. The optimal temperature for root development is between 17 and 24 °C, depending on the genus.

The optimal soil temperature values for root development are shown in *Table 1*.

As the data of the table show, the kinds of apple and peach have a wide, while the kinds of plum have only a narrow optimum range, regarding the root development. In case of plum some degrees deviation may affect root development intensity significantly.

Ferree and Carlson (1987) studied the root development of apple rootstocks and found that the most of them have an optimal temperature interval between 13 and 15 °C. At a larger distance from this range root development falls back and above 28 °C it stops.

In the opinion of most of the authors (*Terts, 1970; Papp-Tamási, 1979*), root development stops only above 35 °C. Some rootstocks ('Malling 7', 'Malling 25', 'Malling-Merton 109' and seedlings) endure higher temperature values better; still it is not true in case of the nowadays wide-spreading dwarf rootstocks (*Gonda, 2000*). Their shallow root is highly sensitive to the warming of soil surface (by sandy soils in can reach 60 °C as well). These soil types have another disadvantage: because of their small water holding capacity the moisture content of the upper soil level is rather low.

As Hungarian results show, root development in the spring time is not caused by the too low soil temperature values, but by the airless circumstances because of too high moisture-content of soils (*Papp – Tamási, 1979*). In our country root development is limited by too low temperature values (just like in 2006), too low amount of precipitation and too high temperature values in the summer time and by the unfavourable distribution of precipitation.

Air temperature

The anomalies in plant development and plant-nutrition caused by air temperature are much more conspicuous than the effects of soil temperature. In the past few years many publications came out about the effects of winter and spring frosts. Here we have only the opportunity to deal with plant nutritional aspects.

Too high or even too low temperature values induce many physiologic reactions in plants that – as mentioned above – basically affect the nutrition of trees.

One of the most important of these physiologic reactions is transpiration. The intensity of water exit from plant surface depends on the air water saturation state, on air temperature, air movement and on nutrient supply factors. Too low temperature causes decreased, while too high values result in too intensive transpiration. Too intensive transpiration – mainly in the noon hours – can result that cells loose their optimal turgescent state and leaves droop or their sides frizzle.

Whether the stomata are open depends on the turgidity pressure of guard cells – that is mainly controlled by the specific K-transport from the neighbour cells into the guard cells. The effect of other alkali ions is not so expressed. Too high accumulation of ions in the cell results in high turgidity and that leads to the opening of the stomata. The accumulation of K^+ in the guard cells depends on the CO_2 concentration in the air: the higher it is, the less K^+ will accumulate in the cells.

In case of heavy droughts the regulation of stomata becomes out of gear. In case of a longer drought period leaves transpire unhindered and in the end they shrivel.

In arid regions it is widely dealt with the application of some chemicals (fungicides, herbicides and metabolism-inhibitors) that affect transpiration and promote a more water sparing plant life.

Toselli et al. (2001) pointed out that both carbon-assimilation and transpiration decreases in drought areas. They also called the attention to the fact that too low root temperature decreases rather the N-adsorption, while drought has a negative effect on gas exchange. On the grounds of these we have to agree the statement of *Wang et al (1998)* that although root transpiration has a great role in nutrient uptake, the effect of soil temperature and moisture content on root transpiration is poorly understood, especially under field conditions.

It is not really common to deal with guttation – not even in plant physiological publications. It appears mainly during stuffy, steamy warm nights. The water drops pressed out from plants play an important role in the detoxification of plants (e.g. overdosage of boron fertilization), but this process is hindered under dry circumstances. The boron amount accumulated in the top of the leaves may cause necrosis and it can lead to nutrient supply problems in cultures that have a higher demand on boron but in addition are sensitive to it. From these it's evident that for the elimination of temperature anomalies the foliar fertilization can be a suitable alternative.

We also point out, that by better nutrient-supply improves the stress resistance of trees. For the boron demand of fruit plantations (first of all of apple sorts) is high, the use of boron containing products is quite wide-spread to enhance fruitset and flowering. The boron content of flowers is relatively high; therefore the reduced boron content in the flowers later results in fertility problems and higher sensitivity against frosts.

Frosts in the flowering period are especially dangerous; they can destroy the whole yield (just as the frosts in May, 2007).

If temperature is below freezing point it is reasonable to apply organic acids (e.g. succinic acid) immediately after the frost, for it can moderate the effect of minus 4–5 °C. It is suggested repeating this procedure after a 5–6 days period, especially in intensive plantations.

These foliar fertilizers with organic acid (dicarboxylic acids) and sugar content induce intensive nutrient transport towards the flowers. Therefore the carbohydrate concentration of flowers increases which protects flowers against the harmful effects of frosts. It has to be added, that these products cannot compensate a temperature fall to minus 6–8 °C over more days, of course (*Nagy, 2007*).

The efficiency of treatments with organic acids can be enhanced by a sufficient K-supply. Potassium plays an important role in synthesis and transport of carbohydrates. In many cases the absolute value of K-content in the leaves is not informative enough about the flowering circumstances. The change of N/K rate and their amount during the flowering period affect the flowering in the next year – presume *Báló et al. (1972)* and *Cerling (1971)*.

As a conclusion we have to agree with *Sansavini and Giannerini (1991)*: although farmers cannot influence weather and its anomalies, still the opportunity to eliminate, soften their effects is given by a practical, reasonable and conscious nutrient-supply and therefore to the achievement of a good yield quality and quantity.

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