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EDITORIAL

Climate change and the future of our world – implications for plant phenology, physiology, plant communities, and crop management

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Climate change is one of the most important challenges of our time. According to the 2014 Intergovernmental Panel on Climate Change (IPCC) report, significant climate changes are occurring in different parts of the world [1]. Global average surface temperature increased by 0.74 ±0.18°C during the last century and it is projected to increase by another 1.1 ±6.0°C in this century [2]. The latest IPCC report [1] indicates that changes in climate patterns have global impacts, i.e., they affect multiple organisms and disturb terrestrial and aquatic ecosystems on all continents. The long-term and short-term changes in weather patterns threaten water resources, agriculture, forestry, social relationships, and human health. Various industrial sectors might experience a significant reduction in their incomes because of weather extremes. In agriculture, climate change will fundamentally alter crop yields and livestock production. It negatively affects multiple components of the food system, i.e., food availability, accessibility, utilization, and stability. In the coming decades, food security can only be accomplished by implementation, adaptation, and mitigation strategies in order to maintain productivity and economic profitability [3].

First we need to define what climate is. One definition refers to the distribution of weather conditions (i.e., mean temperature, mean precipitation, mean humidity, atmospheric pressure, and wind speed) in a particular region during a certain time or season [4]. Another definition addresses the climate system and includes the atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere. In fact, the definition of a climate is not precise and the elements of climate are linked to each other and are widely affected by smaller and/or larger scale conditions (e.g., physiography, geophysical and biogeochemical systems, and human activity). Local and regional climate conditions can influence the climate at the continental, and ultimately, global scale. Our understanding of climate, therefore, should include the consciousness of its natural variability driven by local, regional, and global drivers.

The current issue of *Acta Agrobotanica* is dedicated to the currently observed and projected effects of climate variability on plants and native and managed ecosystems. The implications and interactions are reported by authors representing a range of expertise, including biologists, plant breeders, and ecologist. The issue contains 10 original research papers and two reviews, addressing the following topics: (***i***) phenological observations, the strongest biological signal of climate change, (***ii***) physiological responses of plants to drought stress and increase of temperature, (***iii***) climate impacts on grasslands ecosystems and expected consequences, (***iv***) the need to establish confident quality control of irrigation water, (***v***) revision of current management practices for crops fertilization and/or irrigation to improve crop production and quality, (***vi***) perspectives for introduction of alternative crops that may better cope with progressing climate change. The articles in this issue report research conducted in Bulgaria, Poland, United Kingdom, Ukraine, and the USA.

Most papers presented in this issue emphasize the impact of abrupt weather patterns on blooming biology (e.g., phenology, pollen release and dispersion) and the effects of increasing temperature and decreasing precipitation on plant growth and productivity. Research from Poland and Ukraine has shown that phenological data, both in short- and long-term, are strong bioindicators of the direct impact of changes in weather parameters on plants. Czarnecki and Jabłońska (Poland) have developed a reconstruction model of late spring phenology phases for *Syringa vulgaris* and *Aesculus hippocastanum* for the period 1951 to 2014 using the GIS-based approach, and demonstrated the advancement in the onset of flowering with an average rate of 1.7 days per decade. The authors emphasize that the trend is a result of the rapid increase in air temperature observed after 1990s, while most of the trends for late spring were ambiguous before that period.

The 15-year results of studies conducted by Weryszko-Chmielewska et al. indicate an upward trend in the total annual pollen count in *Acer* species in south-east Poland. Comparing the long-term flowering patterns, the authors have confirmed a shift of the onset of pollen season and the maximum *Acer* pollen concentrations to earlier dates during the spring. The longer periods of allergic pollen presence in the air will have a negative impact on human health.

On the contrary, Kasprzyk, also from Poland, has evidenced that despite the strong tendency towards warmer average annual temperature and its relationship with *Betula pendula* phenophases, there has been no acceleration in flowering and pollen release dates during a 16-year phenological observation period. However, the author suggests that the climate warming effect on the onset and duration of phenophases in *Betula pendula* may require a longer period to be detectable.

The impact of weather conditions on phenological phase of four tree species: *Alnus glutinosa*, *Alnus incana*, *Corylus avellana*, and *Betula pendula* have been studied by Stępalska et al. in Poland during relatively short-term period. However, results indicate the disparity in species reaction on temperature and precipitation. For example, high pollen concentration of *Alnus* and *Corylus* were found as soon as snow cover melted, during sunny days with temperature >10°C and no precipitation. *Betula pendula* pollen appeared when maximum air temperature reached over 20°C. Pollen concentrations increased with intense sunlight lasting over 5 hours per day and declined during precipitation events.

Another interesting contribution is from Lviv city in West Ukraine, where Kalinovych et al. have examined the duration of pollen seasons for *Corylus* and *Alnus* spp. The authors have evidenced considerable fluctuations in the onset of flowering dates up to 43 days (*Corylus*) and up to 31 days (*Alnus*), and documented the occurrence of pollen in the air even during late winter months. The trends correspond with gradual increase in average temperature during February; however, the data were collected only during 2011–2015.

The progressing climate change will affect almost all ecosystem functions. The paper of Belesky and Malinowski presents a very interesting review of grassland communities across regions of the USA. Grasslands represent one of the largest ecosystems on the planet and have a remarkable ability to persist and sustain productivity in response to changing resource conditions and with respect to climatic variation. This resistance and resilience to change, including uncertain long-term weather conditions, establishes managed grasslands as an important means of protecting food security. Authors emphasize the need for further research to identify plant resources and management technologies that strengthen our ability to capitalize upon physiological and anatomical features prevalent in grassland communities associated with varying growing conditions.

Food security is a major challenge for agriculture in changing climate. Increasing plant production is possible due to intensive tillage or the use of high rates of mineral fertilizers. This, however, can lead to adverse ecological effects, including disruption of the basic functions of the soil. Pecio and Jarosz present results of the Catch-C project ("Compatibility of agricultural management practices and types of farming in the EU to enhance climate change mitigation and soil health"). According to the idea of sustainable agriculture, efficient production of safe and high quality food should be accompanied by measures to protect the environment. The authors present the impact of management practices on soil chemical composition and fertility under a range of

soil and climatic conditions. They emphasize that the effects of agricultural practices can be assessed properly only in-long term experiments, where small changes can accumulate over the years to become detectable (i.e., changes in soil organic matter), and interaction with weather variability can be assessed. The analyses of best management practices include different types of tillage, crop rotations and fertilization rates.

Increasing temperature and decreasing precipitation are important climatic variables affecting forage production. In Poland, there are more and more frequent periodic drought occurrences in large areas of the country, resulting in significant losses in agricultural production. Staniak compares yields and nutritional values of selected species and cultivars of forage grasses under optimal moisture condition and long-term drought stress. The results have confirmed that *Dactilis glomerata*, *Festuca pratensis*, *Festulolium braunii*, and *Lolium multiflorum* had significantly lower dry matter yields (on the average by 31%) in response to drought stress when compared with yields achieved under the optimal moisture treatment. The digestibility of dry matter and forage nutritional value of the grasses depend on both the level of soil moisture and grass species. Under drought stress conditions, the digestibility and protein concentration in forage increase when compared with the control treatments.

The changing weather patterns in Central Europe have led to the need for a revision of current standards for fertilization of pulse crops. A 2-year field study (2011–2012) of Klimek-Kopyra et al. has evaluated the effect of phosphorus application on characteristics of the aerial and underground plant parts of different varieties of pea (*Pisum sativum*) and yield components. Results suggest that a higher phosphorus application rate can lead to more rapid vegetative development, manifested as a greater number of leaves and greater leaf area. Moreover, a higher rate of phosphorus application significantly improves the flowering process of pea during soil moisture deficit.

The studies of Shaban et al. performed in Bulgaria show that the extension of the vegetative growth period and delay of the onset of reproductive phase can be effectively achieved by decreasing the temperature of irrigation water and imposing shading. This approach can be adopted as a strategy to ensure the highest productivity of agricultural crops in response to increasing average temperature in the summer as a result of climate change.

The next paper stresses the importance of the quality of irrigation water in horticultural nurseries. In their research, Pettitt and Skjøth from the United Kingdom report that the temperature increase of 2°C in spring can significantly increase the growth rate of oomycetes. Therefore, in respect to climate change, the oomycete colony, predominantly members of the families Saprolegniaceae and Pythiaceae, have considerable value as indicators of the efficacy of irrigation water treatment and cleanliness of storage tanks.

With progressing climate change, there is a need to develop new varieties of crops that are better adapted to altered growing conditions. The progressive increase in temperature and decrease in precipitation during the growing season in Poland requires crops that are resistant to drought. The paper of Prożak introduces *Sorghum* as a new crop for cultivation in Poland. The plant has a multitude of potential uses, i.e., the grain is used to produce porridge, flour, syrup, sugar, ethanol, vegetable oil, starch, wax, paints, and animal fodder (the grain and entire plant). The straw is used to produce fibres, paper, and building materials. Moreover, *Sorghum* has a high energy value and can be an excellent source of bioenergy. Cultivation of *Sorghum* during periodic droughts may be an alternative solution for obtaining fodder when maize cultivation is unreliable.

In conclusion, we believe that these papers substantially contribute to our better understanding of how plants respond to and cope with climate change. We thank all the authors who have undertaken the efforts and prepared manuscripts for this issue of *Acta Agrobotanica*. We would also like to thank all the reviewers for their valuable comments and suggestions on the manuscripts.

Acta Agrobotanica is a scientific journal dedicated to a wide array of flora and fauna interactions in natural and anthropogenically transformed environments. For our future issues, we would like to invite papers, short communications, and reviews dedicated to morphological and biochemical plant responses to abiotic and biotic stressors, including all aspects of plant-animal interactions affected by environmental variables.

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