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From the Editorial Board

Why is Determining the Response of Plants to Multiple Stress Conditions Important for the Development of Breeding Materials?

Since about 30 years ago, when there were debates about whether or not global warming had started, we have now entered a period where we are facing the facts. In a discussion I had as a PhD student with Prof. John Herbert Beynon (Swansea-UK), one of the world's most renowned scientists, I argued that global warming could have devastating effects on agriculture and especially on plant breeding, apart from the popular discussion of melting glaciers and rising sea levels. I had stated that global warming should not have been associated only with an increase in temperature. I clearly remember saying that we might face an increase in other abiotic stressors such as salinity and drought, and other abiotic stressors. When I said that we might even encounter more aggressive races of pathogens as they adapt to these adverse conditions, that concept was a part of my PhD work at that time. He had wisely shown an interest with a mature attitude, and he had said that this could only be fiction, and that the scientific world was approaching it with an exaggeration. From that time, considerably a very short time has passed, and our memory is still fresh to remember those days. Global warming not only results in increases in air, soil, and water pollution but also contributes to ozone depletion through increased CO_2 emissions, allowing UV rays, especially UVB and UVC, to easily reach the earth's surface and cause serious DNA damage to organisms. While high temperatures and drought stress cause crop loss in plants during the period of their presence, heavy metals and UV rays cause fruit and flower deformations both during the period of their presence and in the following years by transferring damaged DNA molecules to the next generation and seriously threaten our future. Under the above conditions, the interaction and combination of almost any abiotic stress factors with each other is possible, as is the interaction and combination of abiotic and biotic stress factors with each other. In recent years, studies on pathogens exposed to abiotic stress have shown that pathogens have become even more aggressive in abiotic stress conditions and even mild pathogens act as serious pathogens under abiotic stress conditions.

In general, when a plant is exposed to biotic stress, it activates its defense mechanism, and when it is exposed to abiotic stress, it either tries to tolerate the stressors by storing them in its vacuoles or other cell cavities, or it tries to escape from the abiotic stressors. To do this, it either closes its stomata or, depending on the situation, increases its respiratory capacity and tries to escape stress by rapidly producing energy. Even if plants are genetically resistant to such conditions, structural and biochemical disturbances in defense or tolerance mechanisms can occur when stress becomes chronic.

In general, plants exposed to dual or multiple stresses may show the additive effect of both stress factors, as well as triggering the defense mechanism of the pathogen, making it more aggressive; studies in this area have accumulated ample amount of data in recent years. In many cases, the plant defense system collapses rapidly due to the destructive effect of combined stress in the short term. In the long run, on the other hand, yield and quality losses are inevitable.

Dual stress can occur between abiotic + abiotic factors as well as abiotic + biotic factors. Stress factors possessing different characteristics can occur simultaneously or sequentially. In this case, the plant's defense mechanism deteriorates unpredictably. Because abiotic and biotic stress factors activate different signaling molecules and enzymatic activities in the plant. Signaling molecules can negatively interact with each other and disrupt the plant's defense system at an early stage. In the mechanism of plant breeding, only plants that can produce the mechanism to resist both stressors will survive. In other words, no matter how resistant a plant can become to a pathogen, the destruction of the defense mechanism will be inevitable if it is exposed to an abiotic agent. Under these conditions, plant breeding will be very complex and take a long time. Acclimation or adaptation of pathogens to constantly changing abiotic stress conditions might also prolong and make plant breeding difficult since the ability of bred plants may be lost during that time.

Mechanisms of induced systemic resistance (ISR) and systemic acquired resistance (SAR) activating the plant immune system become controversial under multiple stress conditions due to conflicting views; therefore, we need comprehensive and detailed studies to clarify this situation. Under these circumstances, we cannot complete highly complex studies with classical experimental methods as in the past and the results of different experimental groups cannot be explained by classical statistical methods. The relationship between each metabolite or molecule in complex stress conditions should be evaluated in a network, and the significant molecular and biochemical pathways which stand out under different stress conditions and combinations should be analyzed. We could then perform breeding and other immunity studies after revealing the pathways. Otherwise, our work, efforts, financial budgets, energy, and most of all our hopes would be wasted.

These studies can even be modelled with Artificial Neural Network (ANN) studies, and even complex structures with no linear relationship between them can be analyzed with ANN. With artificial intelligence methods, even difficult experimental materials or inadequate sampling can be measured with these new techniques. Metabolites and all intracellular and extracellular parameters can be analyzed by the Correlation Network Analysis (CNA) method and the detailed pathway studies can be revealed.

In many parts of the world, especially in the European Union and the United States of America, the process of transition from descriptive biology to modelling biology has already started and it is known that this process will be completed in 2035, and modelling biology studies will be accelerated. For this purpose, the biological pathway mechanisms of each plant are being developed, and the pathway diagnosis of about 10 plants or tree species has already been made. For animal pathways, studies have been conducted on a much larger number of animal species, and almost all human metabolic pathways have been identified. The only remaining areas of study are how these mechanisms change under stress or how they can be maintained and improved. Fewer pathway mechanisms have been studied in plants compared to other species. Pathway studies in other plants are ongoing by researchers at many of the world's major universities and research institutes. The pathways to be uncovered in plants are attempted to be explained with the pathways in the Kyoto Encyclopedia of Genes and Genomes (KEGG) database, but as these pathways are identified in more plants, the specific pathways of each plant will be revealed and the pathway mechanism under stress will be better understood. This will add a new dimension to breeding studies and provide a more solid foundation for plant resistance, tolerance and genetic resistance mechanisms, and it will be possible shortly to breed plants with the desired quality and traits using modelling biology. There may also be a ray of hope for the problem of famine caused by rapid population growth, global warming, and environmental and biological stressors. For example, the FAO estimates that about half of the world's irrigated land is under stress, and the area of these lands continues to increase due to unintentional irrigation, desertification, and high temperatures. Therefore, it is imperative to act quickly in this field and to put the studies into practice as soon as possible.

To maintain healthy cultivation of all crops, all stress conditions to which they are or may be exposed should be studied within a matrix and a laboratory with a state-of-the-art approach should be established on a national basis for this purpose. This laboratory should have the equipment and knowledge to study the stress factors to which many plant species such as cool climate crops (wheat, barley, oats, etc.), industrial crops (cotton, corn, sesame, potatoes, etc.), vegetable crops (tomatoes, peppers, eggplants, etc.), edible legumes (lentils, chickpeas, etc.), ornamental plants, fruit trees, etc. are exposed. Our country has trained researchers in this field and these studies should take their rightful place as soon as possible within the framework of international cooperation with young and dynamic staff.

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