Epigenetics and organic plant breeding

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One characteristic of process oriented organic plant breeding is that all breeding activities from the initial crosses up to final variety propagation are performed under organic growing conditions allowing the plant to interact with its target environment across all generations. However, it is often argued that it is sufficient to select under conventional farming and test the released varieties under organic farming conditions. While for maize (Messmer et al. 2009) and wheat (Reid et al. 2010) it was possible to prove that direct selection for yield under organic farming was more efficient than under conventional farming, it is still a matter of debate if all breeding steps need to be under organic conditions. The recent elucidation of environmentally induced epigenetic mechanisms might deliver insight into the scientific basis for target specific breeding.

Plants have an outstanding ability to adapt to their environment. They have to withstand temperature extremes, drought, nutrient deficiency, radiation, as well as pathogens and herbivores. Plants can respond in a highly dynamic manner involving complex metabolic and/or morphological modifications. The molecular mechanisms for these adjustments of the plant to its environment are still not completely understood. While some adjustments are permanent and stable across generations, others are only of preliminary nature, like the acclimatization of a plant to cool growing conditions or the change into the reproductive phase after vernalisation. The DNA sequence as well as its expression pattern in response to stress are crucial for the adaptability of a genotype. Recently discovered epigenetic systems play a key role for genomic gene function at a higher level hierarchy, ranging from transducing environmental signals to altering gene expression, genomic architecture and defence of plants (Grant-Downtown and Dickinson 2006). Until now three mechanisms have been identified for the epigenetic gene regulation: DNA methylation, histone modification and RNA-interference. These interacting epigenetic systems can regulate expression or silencing of genes, resulting in epigenetically controlled phenotypes (Tsaftaris et al. 2008; Fossey 2009) and are often in conflict with Mendelian genetic models. Epigenetic alleles can result from a genome response to stressful environments and may enable plants to tolerate stress (Tsaftaris et al. 2008). While most of these stress induced modifications are reset to the basal level once the stress is relieved, some modifications are stable and mitotically or meiotically transmitted as stress memory permitting heritability of acquired characteristics (Chinnusamy and Zhu 2009). Epigenetic variations can be generated at a much higher rate than genetic ones. Especially under rapidly changing environmental conditions several new advantageous epimutations may be induced simultaneously in the same individual. Recent studies outlined the importance of epigenetic inheritance as an additional source of variation for selecting superior genotypes (King et al. 2009; Tsaftaris et al. 2008).

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