내동성(耐凍性) 및 내한성(耐寒性)에 대한 최근의 분자유전학 연구동향

작물시험장 수도육종과 송 문 태

A Recent Development of Molecular Genetics of Freezing Tolerance and Winter Hardiness in Higher Plants

Crop Experiment Station, RDA : Moontae Song

Introduction :

Winter hardiness has been the subject of considerable investigation and the development of cultivars with improved winter hardines is of primary concern, However, the introduction of new cultivars that possess increased winter hardiness has not always been succesful. Moreoer, there were several difficulties to be encountred to make selection of winter-hardy varieties by conventional field trials. Several methods to combine with the field selection is discussed here.

Winter hardiness is involved several factors under field condition of which freezing tolerance is the most important. Several genes which are beleived to be involved in cold acclimation and freezing tolerance were isolated in higher plants. The studies on the practical use of these genes as molecular marker for the selection has been under progressing as well as their functional and regulational studies.

Mechanisms of freezing injury in plant :

At normal freezing rates under natural conditions, ice nucleation occurs initially outside cell because the cell has a lower freezing point than the extracellular water. The resultant lowering of extracellular water potential cause more water to leave the cell to form extracellular ice, resulting in protoplasmic dehydration and mechanical collapse of membrane. During very rapid cooling, ice nucleation occur inside the cell which is lethal to the cell and plant, since the presence of intracellular ice disrupts the cellular membrane. However, freezing rate sufficiently rapid to cause intracellular freezing are not commonly encountered in the natural environment. There is a general agreement that under conditions of extracellular ice formation, decrease in temperature or the presence of ice crystal per se is not responsible for freezing damage, and that the process of cellular dehydration is the most disruptive and injurious component of freezing injury.

Cold acclimation and biochemical changes during cold acclimation :

Temperate plants, possessing the appropriate genes, are able to acclimate to freezing temperature following a period of low but nonfreezing temperature treatment (Cold acclimation). The most dramatic effect of cold acclimation, although involved in a variety of physical and biochemical changes, is increased freezing tolerance.

Several biochemical as well as physiological changes occurs during cold acclimation : alteration in lipid composition, increased sugar and soluble protein, appearence of new isozyme form, and inhibition of photosynthesis. However, it is uncertain whether these changes are associated with increased freezing tolerance, or whether they are manifestatons of metabolic adjustments in respose to cold temperature. Some may contribute to the overall fitness of the plant for low temperature survival, while others have specific roles in bringing about increased freezing tolerance.

Molecular genetics of cold acclimation

Cold acclimation involves changes in gene expression. Direct evidence was obtained recently to show low temperature induced accumulation of specific mRNAs in several higher plants. DNA sequences corresponding to these cold-regulated transcripts (cor genes) have also been isolated and characterized by differential screening of cDNA libraries constructed from these species.

Althogh their functions in freezing tolerance are not been elucidated yet, their sequence homology to known genes suggestes their roles as protectant to dessication, antinucleating agent and cryoprotectant. The functions of these genes will be adressed in future by using transformation of mutant plants with the genes, antisense RNA technique, or in situ location of products of the transcripts of the genes. Some other researchers have adressed the question whether cor gene expression correlates with the degree of freezing tolerance attained during cold acclimation in several plant species with several cor genes. However, the results have been not consistant depending on plant species and the genes examined.

Futher prospect

Winter hardiness implies avoidance of or tolerance to the cumulative effects of winter that a plant encounters, including freezing, heaving, smothering, dessication, and disease infestitation. Climate, soil, plant, and cultural practices interact to determine the degree of injury to a crop following the rigor of winter. Tolerance and avoidance mechanisms may reside at either the whole plant, tissue, or cellular level. Thus, the undertaking to increase winter hardiness is indeed an ambitious objective, and one that may be insurmountable if approached in its entirety. In this respect, there should be more effective methods to screen the winter-hardy plants well combined with conventional selection methods. One of the approach can be a molecular markers which has a linker between the freezing tolerance and its expression. Or, with the advancement of molecular genetics, the DNA marks in RFLP or physical mapping can be used for the marker for the selection or isolation of the very genes which are involved in freezing tolerance of higher plants.

Breeding the hardy cultivars is long-term solution of the problems. As a shor-term solution, application of the chemicals or some cultural practice can be applied to cope with the rigor of winter if there are more information on the mechanism and physiology of freezing tolerance and winter hardiness.