

Vitro Plant Regeneration

Subjects: Plant Sciences

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Plants generally have the highest regenerative ability because they show a high degree of developmental plasticity. Although the basic principles of plant regeneration date back many years, understanding the cellular, molecular, and physiological mechanisms based on these principles is currently in progress. In addition to the significant effects of some factors such as medium components, phytohormones, explant type, and light on the regeneration ability of an explant, recent reports evidence the involvement of molecular signals in organogenesis and embryogenesis responses to explant wounding, induced plant cell death, and phytohormones interaction. However, some cellular behaviors such as the occurrence of somaclonal variations and abnormalities during the in vitro plant regeneration process may be associated with adverse effects on the efficacy of plant regeneration. A review of past studies suggests that, in some cases, regeneration in plants involves the reprogramming of distinct somatic cells, while in others, it is induced by the activation of relatively undifferentiated cells in somatic tissues. However, this review covers the most important factors involved in the process of plant regeneration and discusses the mechanisms by which plants monitor this process.

Keywords: abnormalities ; in vitro regeneration ; micropropagation ; organogenesis ; somatic embryogenesis

1. Introduction

The initiation of in vitro studies of plant cells and tissue culture dates back to 1902, when Gottlieb Haberland presented a “totipotency” hypothesis that each cell has all the genetic information needed to produce a perfect plant ^{[1][2]}. Differentiated cells in plants are able to re-enter the cell cycle, proliferate and regenerate tissues and organs, and even become a complete plant, according to this hypothesis. Several reports have shown the totipotent ability of plant cells through which the plant can be regenerated, which in turn is widely used in several basic studies such as in micropropagation, germplasm conservation, and formation of genetically modified plants ^{[3][4]}. Plants have powerful regenerative abilities thanks to the property of developmental plasticity of their cells ^{[5][6]}. In vitro plant regeneration is a process in which explants, after undergoing cell division and differentiation, form organs and tissues throughout their growth period ^{[7][8]}. In vitro plant regeneration can be performed via somatic embryogenesis or organogenesis ^[9]. Organogenesis is the process by which new organs and even whole plants are usually formed in response to wounds from other parts of the organs. In somatic embryogenesis, first, a structural cell similar to zygotic embryos is formed, and then the entire plant is regenerated ^{[6][10][11][12][13]}. The potential for plant regeneration, which has long been used to propagate clones, cuttings, and grafts, is the basis of ongoing research and agricultural applications ^[14]. Micropropagation has been applied commercially worldwide, although the capability of plant regeneration varies significantly in different genotypes ^{[6][14][15][16]}. During the last several years, several agents regulating plant regeneration have been studied, such as exogenously supplied phytohormones in vitro ^{[17][18][19]}, explant type ^{[5][20][21][22]}, physiological properties of the donor plants ^{[23][24]}, mineral uptake and their distribution patterns ^{[25][26]}, changes in mevalonate kinase activity ^[27], and reprogramming of differentiated somatic cells and activation of relatively undifferentiated cells in somatic tissues ^[6]. Nontraditional inducers such as some amino acids ^[28]; light intensity and quality ^[29]; weak electric current ^[30]; and some antibiotics, for example, cefotaxime ^[31], have also been reported to affect in vitro plant regeneration. Rathore and Goldsworthy ^[30] passed very weak electric current 1 microamp between the tissue and the culture medium and noticed a dramatic increase in tobacco callus growth. Azmi et al. ^[32] reported the beneficial effects of a mixed light color of LED (red and blue) on in vitro plant regeneration of *Rosa kordesii*. This review covers novel findings of how plants adjust regeneration in terms of the cellular, molecular and physiological aspects and discuss influence of developmental and environmental factors on plant regeneration efficiency.

2. Development

What we can understand from reviewing past studies is that many of the events that occur during the plant regeneration process can be controlled by manipulating signaling pathways related to the interaction of phytohormones, explant wounding, and programmed cell death. Although the key regulators of hormone signaling pathways have been previously

discovered, more work is needed to understand how they retrieve cell proliferative capacity. We need to address a few questions: how explants understand and transmit endogenous and environmental signals, and how they induce or maintain cell differentiation. Moreover, it would be useful to study different mechanisms at both the molecular and physiological levels by which the explants regulate in vitro regeneration. The prospects of gene editing in differentiation of recalcitrant plants are as follows: we are still faced with a challenge of genetic dependence on in vitro plant regeneration via organogenesis, somatic embryogenesis, androgenesis, and protoplast regeneration. A big question is, can we have a common culture medium for most of the genotypes of different plants? The application of innovative tools with a multidisciplinary approach to address issues of in vitro plant regeneration for wider applications in crop improvement, commercial applications, and secondary metabolites should be investigated.

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