E4. The Role of Hormones during Seed Development and Germination

Ruth R. Finkelstein
Department of Molecular, Cellular, and Developmental Biology, University of California at Santa Barbara, Santa Barbara, CA 93106 USA.
E-mail: finkelst@lifesci.ucsb.edu

INTRODUCTION

Seed production is an extraordinary adaptation to a terrestrial environment that permits plants to reproduce under dry conditions and broadly disperse their progeny, which can then survive in an arrested state until environmental conditions favor growth of the next generation. Although there are many anecdotal reports of extreme longevity, the current record for documented viability is over 1000 years for an Indian Lotus seed, collected from an ancient lake bed in China. To accomplish this remarkable feat, seeds contain an embryo and a supply of nutrient reserves, packaged as a dry desiccation-tolerant unit. The features that make seeds an effective means of reproduction (high nutrient content and extended viability during developmental arrest) also make them a convenient food supply, and led to the development of civilizations in cultures that made use of this dependable source of crops to supply themselves with food. Consequently, features such as nutrient content, yield, and germination control are of major agronomic importance and have been the focus of much research.

Seed development contrasts from vegetative growth in that embryogenesis is relatively insulated from environmental effects such that the final product is fairly constant even though the growth rate may vary. This constancy reflects the activity of regulatory mechanisms that lead to an ordered progression through three phases of embryo development: morphogenesis, cell enlargement/reserve accumulation, and desiccation/developmental arrest (Fig. 1). During the morphogenesis phase, the zygote undergoes extensive cell division and differentiation of tissue types to build a miniature plant with a root-shoot axis and the three major tissues of a mature plant: vascular, ground, and dermal. This phase of embryonic development is accompanied by development of the endosperm, which serves as a source of nutrient reserves for the embryo that may continue to grow and persist in the mature seed or be resorbed during the latter phases of seed development.

1Abbreviations: AtIP5P, Ins(1,4,5)P35 phosphatase; Em, Early methionine-labeled; LEA, Late embryogenesis abundant; PLC, Phospholipase C.
Hormones in seed development and germination

depending on the species. During the final two phases of seed development, also known as maturation, the embryo and seed prepare for survival when separated from the maternal plant. Toward this end, seeds accumulate reserves to provide nutrients for survival during germination. Depending on the species, storage reserves may accumulate exclusively in the embryo itself, or in both the embryo and endosperm. The developing embryos undergo a transition from growth by cell division to cell enlargement as they begin to accumulate storage reserves. Finally, most seeds prepare for and undergo water loss to achieve a developmentally-arrested, desiccation-tolerant state that permits survival with as little as ~10% free water. The degree of arrest varies among species, ranging from true dormancy (literally, “sleeping”) that requires specific environmental cues such as light or chilling to induce germination, to “quiescence” which requires only sufficient water for resumed growth.

Germination involves a reactivation of metabolic activity, a re-differentiation of embryonic tissues to mobilize the reserves they stored, and a shift to growth by meristematic activity. Because completion of germination results in loss of desiccation tolerance, this step constitutes a commitment to growth of the next generation. Consequently, the transition from seed to seedling is highly sensitive to many environmental factors, including light, temperature, and availability of water. Response to many of these environmental signals is mediated by, or interacts with, signaling via one or more hormones.

Figure 1. A generalized graph showing the relative levels of water, dry and fresh weights (DW and FW), and hormones during the stages of embryo and seedling development. Time periods associated with each phase of development vary with species and are not included. Developmental arrest may be either quiescence or dormancy, depending on the species. (Adapted from 47)