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Presiding: Anwar A. Khan

Quantification of Plant Dormancy: Introduction to the Workshop

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Quantification of Seed Dormancy: Physiological and Molecular Considerations

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Quantification of Plant Dormancy: Introduction to the Workshop

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Dormancy is a physiological state that reduces the ability of a seed or bud to germinate or grow. Dormancy is controlled by 1) factors residing in the embryo or bud (endodormancy, primary dormancy); 2) plant-situated factors outside the embryo or bud, such as covering structures or a terminal bud, which may exert a mechanical, chemical, or correlative inhibition (paradormancy, coat-imposed dormancy); and 3) environmental factors, such as high temperature, unfavorable irradiation or photoperiod, a low water potential sowing medium, applied chemical inhibitors, etc. (ecodormancy, induced dormancy). Although a variety of terms have been used to describe dormancy types in seeds and buds, based on the factors that influence dormancy, the underlying mechanism controlling embryo and bud dormancy may be the same (Khan, 1975). Stress factors, such as noted under 2) and 3) above, can induce dormancy by affecting the dormancy regulating mechanism, but their effect appears to be indirect. Factors such as far-red irradiation and gibberellin (GA) synthesis inhibitors appear to induce dormancy more rapidly, at least in seeds, indicating that their action is more direct (Khan, 1994). Similarly, GA, irradiation and moist-chilling are directly involved in dormancy release and prevention, unlike the stress-alleviating factors, such as cytokinins and ethylene, which indirectly affect dormancy release.

Measurable changes in germination or growth potential in the embryo or bud occurring naturally or induced by artificial means can be used to quantify dormancy. These include changes in the mechanical constraints of the covering structures (seedcoat, bud scales), water potential of the medium, hormone levels, synthesis of macromolecules, duration of exposure to chilling temperatures or chilling units, duration of soaking in darkness (for seeds with skotodormancy), the amount of indoleacetic acid (IAA) replacing the terminal bud, etc., in relation to dormancy induction, intensification, or release. The quantification of dormancy using this approach is largely correlative and

does not deal directly with the inherent causes of embryo or bud dormancy.

Dormancy induction and release in seeds has been shown to be a reversible process, occurring under a wide variety of conditions (Khan, 1994). The evidence to date points to an association of dormancy release and maintenance with phase transitions and compositional changes in cell membranes. Dormancy release is activated by membrane-active agents, including red light, brief high-temperature shifts, osmotic shock, anaesthetics, and moist-chilling. These agents initiate production of an array of bioactive chemicals, some of which (e.g., GAs) may act more directly than others to release the dormancy. Dormancy release or prevention by GA or irradiation is independent of germination and can be shown under conditions when germination is inhibited, e.g., by high temperature, low water potential, or abscisic acid (ABA). The inability to produce active GAs may be related to dormancy maintenance.

Studies with seeds and buds indicate that dormancy release by GA, irradiation, decapitation, or moist-chilling is associated with enhanced expression of certain genes; in the absence of these treatments, genes are not expressed (Stafstrom and Sussex, 1993; Toyomasu et al., 1995). In other cases, the transcript levels of other genes increases in dormant embryos and nondormant embryos exposed to ABA or a stressful environment, while the levels decline rapidly in nondormant embryos (Goldmark et al., 1992; Li and Foley, 1995). Thus, a major difficulty has been to distinguish between stress-related (imposition or alleviation) gene expression from that associated with dormancy induction and release. In absence of a clear understanding of the underlying mechanism of bud and embryo dormancy, conflicting theories are bound to appear.

The papers presented at this workshop discuss the various factors influencing dormancy in seeds and buds and the conceptual framework necessary for quantifying dormancy. The first two articles are devoted to dormancy quantification in seeds and the next two to the quantification in buds. The article by Khan describes the various physiological approaches that have been used to quantify dormancy and touches upon the molecular approaches indicative of dormancy

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induction and release. Seeley focuses attention on the endodormancy of woody species and stresses the point that in the absence of direct methods, indirect methods must be used to quantify seed dormancy. The immensity of the problem is clearly evident in the remark by Seeley "...in the obvious unknown ED (endodormancy) milieu, how can we measure its intensity, its transition and its release?" Fuchigami and Wisniewski emphasize the benefits of developing quantitative systems of classifying dormancy in buds. They present a conceptual numerical model based on growth stages divisible into numerical units that would likely lead to improved understanding and quantification of dormancy. Faust et al. discuss the roles of hormonal, chemical, and physical factors in bud dormancy, making a compelling argument for the role of bound vs. free water in the control of endodormancy. This article proposes several biochemical and physiological approaches for measuring dormancy.

The workshop was the first attempt at quantifying plant dormancy. It provided an excellent opportunity to review the state of our knowledge of plant dormancy, the differences and similarities in seed and bud dormancy, and the various approaches used to quantify them. The participants hope that it will serve as a forerunner for future workshops or colloquia for reporting progress in this important area of plant development.

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Quantification of Seed Dormancy: Physiological and Molecular Considerations

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Physiological and biochemical controls needed to induce, maintain, and release seed dormancy are not clearly understood and hence it has been difficult to quantify dormancy. The studies on dormancy have dealt with the changes in embryo growth potential or germinability in relation to the controlling factors within the embryo, covering structures and environmental stimuli or their combinations in a dose-related fashion. More recently, attempts have been made to relate dormancy maintenance and release to temporal cellular and molecular changes, and conflicting theories or mechanisms for the control of dormancy have been advanced. This situation has made the task of quantifying dormancy quite difficult. For example, several genes or cDNA clones have been identified from dormant seeds and the temporal changes in the mRNA transcript levels of these genes during hydration, using labeled cDNA as a probe, have been studied. The transcript levels increase (Toyomasu et al., 1995) or decline and disappear (Goldmark et al., 1992; Li and Foley, 1995) in response to GA.

This article describes the various approaches that have been employed to quantify dormancy induction, maintenance, and release. They are based on the performance of seed in relation to the changes in the strength of the embryo covering structures, the effects of the environmental stimuli, responsiveness to hormones, hormone concentrations, RNA and protein synthesis, mRNA transcript levels of a cDNA clone, or combinations thereof.

COVERING STRUCTURES AND EMBRYO GROWTH POTENTIAL

Strength of covering structures and dormancy intensity. Indian ricegrass [*Oryzopsis hymenoides* (Roem. & Shult.) Ricker] seeds have

seedcoat (lemma and palea) and embryo dormancy (McDonald and Khan, 1977). Increasing the period of scarification with sulfuric acid progressively increased the germination percentage. Germination percentage increased linearly with the increase in scarification time (Fig. 1). Younger seeds (1971 vs. 1970 harvest) were more resistant to

Fig. 1. Relationship between sulfuric acid scarification time and germination of Indian ricegrass seeds harvested in 1970, 1971, and 1973. Appropriate regression equations were generated to fit the data (from McDonald and Khan, 1977).

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