From Forest Nursery Notes, Summer 2011

139. © To germinate or not to germinate: more than just a question of dormancy.
Thompson, K. and Ooi, M. K. J. Seed Science Research 20:209-211. 2010.

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Seed Science Research (2010) **20**, 209–211
doi:10.1017/S0960258510000267

RESEARCH OPINION

To germinate or not to germinate: more than just a question of dormancy

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(Received 3 August 2010; accepted after revision 17 August 2010; first published online 24 September 2010)

Keywords: dormancy, germination, light, nitrate, restoration, smoke, temperature

Consider the following four quotations concerning the distinction between breaking dormancy and stimulating germination.

> To many people, seed dormancy simply means that a seed has not germinated, but we will soon see that this definition is inadequate. Unfavourable environmental conditions are one reason for lack of seed germination. That is, seeds could be in a paper bag on the laboratory shelf (i.e. lack of water), buried in mud at the bottom of a lake (i.e. insufficient oxygen and/or light), or exposed to temperatures that are above or below those suitable for plant growth. These obviously unfavourable conditions for germination are examples of how the environment rather than some factor associated with the seed *per se* prevents germination. A second reason why seeds may not germinate is that some property of the seed (or dispersal unit) prevents it. Thus, the lack of germination is a seed rather than an environmental problem. Dormancy that results from some characteristic of the seed is called organic dormancy, and this type of dormancy usually is of most interest to seed biologists and ecologists. (Baskin and Baskin, 1998)
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> The switch to germination represents a transition to or from one stable non-germinating state to another germinating state. As such, germination control can be viewed as a classical bifurcating system with two stable attracting states: non-germination and germination (Tyson *et al.*, 2003). In-between lies a critical unstable transition that is passed as the system flips from the unstable state that provides the borderline (and thus quantifies the critical point for transition) between the two stable ones. The role of dormancy is to modify the sensitivity of seeds to signals that flip the switch. (Penfield and King, 2009).
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> … the distinction between the agents responsible for dormancy alleviation (time, temperature and moisture) and those germination agents such as smoke (butenolide), nitrates and light whose roles are more appropriately defined as germination stimulants that act only once dormancy has been alleviated. (Merritt *et al.*, 2007)
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> If one equates dormancy with failure of germination, Vegis' theory would imply that, except for seeds that are fully dormant, the dormancy of seeds kept at a temperature outside the range required for germination can be relieved by transferring them to a temperature inside this range. This view is shared by Bewley & Black (1982), who stated that dormancy may vary with external conditions, usually of temperature. On the other hand, dormancy is supposed to be an adaptive trait (e.g. Simpson, 1990). This implies that dormancy should not be a measure of the external conditions a seed is currently exposed to, but be a characteristic of the seed. We believe that these inconsistencies result from an inaccurate definition of dormancy. Firstly, dormancy should be able to have any value between all and nothing, and, secondly, it should be a seed trait (cf. Gordon, 1973).

Karssen (1982) emphasized that seasonal periodicity in the field-emergence of annuals is the combined result of seasonal periodicity in the field temperature and seasonal periodicity in the width of the range of temperatures suited for germination. Germination in the field is restricted to the period when the field temperature and the temperature range over which germination can proceed overlap. Dormancy is only related to the width of the temperature range for germination, not to the question whether or not the current temperature is inside this range. Derkx & Karssen (1993a) showed that in *Sisymbrium officinale* changes in dormancy not only comprise changes in temperature requirements for germination, but also in its requirements for nitrate and light. Sensitivity to light and nitrate, both necessary

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