

Seed Dormancy Mechanisms in Vegetable Crop Species

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Abstract

Seed dormancy is a physical or physiological condition of a viable seed which prevents germination even in the presence of otherwise favorable conditions for germination. This paper will review the types of dormancy observed for various vegetable crop species, and the methods available for dormancy breaking.

Introduction

Seeds often reveal complex and effective mechanisms which ensure survival under many environments and temporal situations. While most vegetable species and commercially important cultivars are relatively free of dormancy mechanisms, members of the *Apiaceae*, *Asteraceae*, *Malvaceae*, *Solanaceae* and *Chenopodiaceae* are among the families with erratic germination due to seed dormancy (Carter and Vavrina, 2001; Gray, 1975; Leskovar et al., 1999; Nascimento et al., 2000). Seed dormancy is not merely a resting state in the absence of suitable conditions for germination, which is more correctly referred to as quiescence (Copeland and McDonald, 2001). Several physical and physiological types of dormancy, and techniques for breaking dormancy will be highlighted below.

Dormancy Types, and Methods to Break Dormancy

Primary seed dormancy is more common in nature than secondary dormancy, and can be in the form of exogenous or endogenous dormancy. Exogenous primary dormancy is a condition where essential inputs (e.g. water, light, temperature) are not available to the seed, and germination does not occur. Genetics and environmental factors can also modify the expression of exogenous dormancy, especially for traits such as hardseededness. Physical barriers, such as seed (fruit) coats impermeable to water and/or gases, is reported for vegetable species in the *Fabaceae*, *Malvaceae* (okra), and a number of other families (Copeland and McDonald, 2001). Chemical exogenous dormancy due to germination inhibitors in the seed (fruit) coat can also be observed in vegetable crops, such as spinach and parsley (Leskovar et al., 1999; Wien, 1997). Break methods for these dormancy mechanisms in nature include microbial action, freeze-thaw temperature cycles, and ingestion by animals. Lab techniques generally employ mechanical

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or chemical scarification processes to crack or partially remove the seed coat. Protocols (duration and compounds) used for the treatments are critical to success, since seed damage or failure to break dormancy may result from excessive or insufficient treatment, respectively (AOSA, 1999; ISTA, 1993; McDonald and Copeland, 1997; Vivrette, 2001).

Endogenous primary dormancy can also be influenced by many environmental factors during seed development and maturation. Daylength, temperatures, seed position in the fruit or inflorescence (see Table 1), age of the mother plant, and plant or seed moisture status can be linked to dormancy levels in some species. Rudimentary embryos, and the need for embryo after-ripening is one form of endogenous dormancy. A more encompassing type of endogenous dormancy is termed physiological dormancy. Physiological dormancy is linked to seed metabolic rates, regulated by the presence of endogenous growth promoters and inhibitors (e.g. phenolics, cyanogenic compounds, ABA, GA's, cytokinins). These endogenous promoters and inhibitors will also interact with environmental factors such as light and temperature.

A second type of physiological dormancy is linked to the osmotic effects of high sugars or salts in the seed or fruit (e.g. beet). These osmotic effects may prevent full imbibition, thereby preventing or slowing germination (Copeland and McDonald, 2001).

Break methods for endogenous (physiological) dormancy rely on 1) leaching, 2) mechanical or chemical scarification, and 3) stratification to adjust inhibitor-promoter balance (AOSA, 1999; ISTA, 1993). Prechilling seed treatments (at 3° - 10°C) for variable durations are common. For after-ripening species (e.g. many cereal crops), storage at 15° - 20°C for one to two months is often adequate for good germination (Bewley and Black, 1994). Other species may benefit from various chemical (Table 2) or growth regulator (Table 3) treatments, with or without light.

Secondary dormancy mechanisms (e.g. thermodormancy, photodormancy, skotodormancy) are also observed in some vegetable species (Table 4). If lettuce seed (most cultivars) is subjected to temperatures of 30°C or above during imbibition, it becomes dormant and is delayed in germination (Gray, 1977; Thomas et al., 1979; Wien, 1997). The exact mechanism is still under debate (Nascimento et al., 2000). Ethylene production, and enzyme activity (endo-B-mannanase) weakening the endosperm tissue around the radicle tip are noted for thermotolerance in lettuce. Similar roles of ethephon and GA have been studied for pepper seed germination (Carter and Stevens, 1998).

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References

- Association of Official Seed Analysts (AOSA). 1999. Rules for Testing Seeds. Lincoln, Nebraska.
- Bewley, J.D. and M. Black. 1994. Seeds: Physiology of Development and Germination, 2nd ed. Plenum Press. New York, 445 p.
- Carter, A.K. and R. Stevens. 1998. Using ethephon and GA₃ to overcome thermoinhibition in 'Jalapeno M' pepper seed. HortScience 33:1026-1027.
- Carter, A.K. and C.S. Vavrina. 2001. High temperature inhibits germination of jalape_o and cayenne peppers. HortScience 36:724-725.
- Copeland, L.O. and M.B. McDonald. 2001. Principles of Seed Science and Technology, 4th ed. Kluwer Acad. Press.
- Gray, D. 1975. Effects of temperature on the germination and emergence of lettuce (*Lactuca sativa*) cultivars. HortScience 50:349-361.
- Intl. Seed Testing Association (ISTA). 1993. International Rules for Seed Testing. Seed Sci. and Technol. 31:1-288. (supplement). Zurich, Switzerland.
- Leskovar, D.I., V. Esensee, and H. Belefaut-Miller. 1999. Pericarp, leachate, and carbohydrate involvement on thermo-inhibition of germinating spinach seeds. J. Amer. Soc. Hort. Sci. 124:301-306.
- McDonald, M.B. and L. Copeland. 1997. Seed Production: Principles and Practices. Chapman and Hall, New York, NY. 249 p.
- Nascimento, W.M., D.J. Cantliffe, and D.J. Huber. 2000. Thermotolerance in lettuce seeds: Association with ethylene and endo-B-mannanase. J. Amer. Soc. Hort. Sci. 125:518-524.
- Thomas, T.H., N.L. Biddington and D.F. O'Toole. 1979. Relationship between position on the parent plant and dormancy characteristics of seed of three cultivars of celery (*Apium graveolens*). Physiol. Plant. 45:492-496.
- Vivrette, N. 2001. Seed Dormancy (Chapt. 9) *In*: Seed Technologist Training Manual; Soc. of Comm. Seed Technologists; M. McDonald, T. Gutormson, B. Turnipseed (eds.).
- Wien, H. C. 1997. The Physiology of Vegetable Crops. CAB Intl., New York, NY. 662 p.

Table 1. Umbel position, seed weight (mg) and germination (%) after 21 days at 18°C in light, in three celery (*Apium graveolens*) cultivars. LSD and 5% in parentheses.

Cultivars	Umbel position	Mean seed weight (mg)	Germination (%)
Green snap	Primary	0.590	51
	Secondary	0.440	85
	Tertiary	0.386	94
	Quaternary	0.382	80
		(0.069)	(9.8)
Lathom Blanching	Primary	0.474	50
	Secondary	0.438	72
	Tertiary	0.380	94
	Quaternary	0.348	82
		(0.069)	(9.2)
Ely White	Primary	0.590	59
	Secondary	0.468	62
	Tertiary	0.490	80
	Quaternary	0.520	87
		(0.086)	(7.3)

Source: Thomas *et al.* (1979).

Table 2. Some chemicals that break seed dormancy.

Class	Example
Respiratory inhibitors	
Cyanide	<i>Lactuca sativa</i>
Azide	<i>Hordeum vulgare</i> *
Iodoacetate	<i>Hordeum vulgare</i> *
Dinitrophenol	<i>Lactuca sativa</i>
Sulphydryl compounds	
Dithiothreitol	<i>Hordeum vulgare</i> *
2-Mercaptoethanol	<i>Hordeum vulgare</i> *
Oxidants	
Hypochlorite	<i>Avena fatua</i>
Oxygen	<i>Xanthium strumarium</i> *
Nitrogenous compounds	
Nitrate	<i>Lactuca sativa</i>
Nitrite	<i>Hordeum vulgare</i> *
Thiourea	<i>Lactuca sativa</i>
Growth regulators	
Gibberellins	<i>Lactuca sativa</i>
Cytokinins	<i>Lactuca sativa</i>
Ethylene	<i>Chenopodium album</i>
Various	
Ethanol	<i>Panicum capillare</i>
Methylene blue	<i>Hordeum vulgare</i> *
Ethyl ether	<i>Panicum capillare</i>
Fusicoccin	<i>Lactuca sativa</i>

* modified, National Plant Data Center, 2002.

Source: Bewley and Black, 1994.

Table 3. Breaking of dormancy by some growth regulators.

Species	Factor breaking dormancy	Effect of growth regulator ¹		
		GA ²	CK ³	Ethylene
<i>Apium graveolens</i>	Light	+	-	+
<i>Avena fatua</i>	Afterripening, chilling	+	-	+
<i>Corylus avellana</i>	Chilling	+	-	-
<i>Hordeum vulgare</i> *	Afterripening, chilling	+	-	+
<i>Lactuca sativa</i>	Light	+	±	-
<i>Lamium amplexicaule</i>	Light	+	nr	nr
<i>Malus sylvestris</i> *	Chilling	-	+	nr
<i>Ruellia humilis</i>	Chilling	+	nr	nr
<i>Xanthium strumarium</i> *	Afterripening	+	-	+

¹ +, Regulator effective; -, regulator ineffective; ±, moderately effective; nr, not recorded.

² GA, gibberellin (usually gibberellic acid GA₃, or GA₄, GA₇).

³ CK, cytokinin (usually kinetin, benzyladenine).

* Modified, National Plant Data Center, 2002.

Source: Bewley and Black, 1994.

Table 4. Factors inducing secondary dormancy.

Inducing factor	Example
Anaerobic conditions	<i>Xanthium strumarium</i> *
Darkness (skotodormancy)	<i>Lactuca sativa</i>
	<i>Lamium amplexicaule</i>
	<i>Phleum pratense</i>
Prolonged white light (photodormancy)	<i>Lactuca sativa</i>
	<i>Nemophila insignis</i>
	<i>Phacelia tanacetifolia</i>
Prolonged far-red light (photodormancy)	<i>Arabis hirsuta</i>
	<i>Amaranthus caudatus</i>
	<i>Lactuca sativa</i>
Temperatures above maximum for germination	<i>Ambrosia trifida</i>
	<i>Avena sativa</i>
	<i>Chenopodium bonus-henricus</i>
	<i>Taraxacum megalorhizon</i>
Temperatures below minimum for germination	<i>Phacelia dubia</i>
	<i>Taraxacum megalorhizon</i>
	<i>Torilis japonica</i>
Water stress	<i>Lactuca sativa</i>

*Modified, National Plant Data Center, 2002.

Source: Bewley and Black, 1994.