Impact of seed technology on seed germination in horticultural crops©

R.L. Geneve[a]

Department of Horticulture, University of Kentucky, Lexington, Kentucky 40546, USA.

INTRODUCTION

The relatively high initial cost of horticultural seeds has led growers to employ precision seeding and transplant production systems to maximize seedling stands. This places a high reliance on high quality seeds for maximal seedling emergence and uniformity. Specialization has led to increased capital investment in modern greenhouses, automated seeders and sophisticated transplanting robots. This has challenged the seed industry to provide seeds that perform under these demanding production systems.

The two aspects of seed technology that directly impact growers are seed testing and seed coating. The goal of seed testing is to provide useful information on a seed lot's quality. This is accomplished using standard germination and vigor testing. Standard germination evaluates the seed's ability to produce a normal seedling under near-optimal germination conditions. This is important information, but does not always reflect future greenhouse emergence. Seed vigor testing attempts to determine the potential for rapid, uniform emergence under non-uniform (i.e., greenhouse) germination conditions. It becomes apparent that seed lots with comparable standard germination percentages can vary widely in their vigor and that vigor testing can often provide a better predictive measure of seedling emergence.

The major seed coatings for greenhouse crops include seed pelleting and film coating. They are designed to facilitate mechanical sowing and can act as carriers of chemical or biological seed additives. The objective of this manuscript is to provide a brief overview of seed vigor testing methods and seed coating treatments.

SEED VIGOR TESTING

Standard germination is usually required to be reported for each seed lot offered for commercial sale. However, vigor test results are not routinely available to growers and must be requested separately. If they are not available from the seed seller, growers can send samples to a private seed testing lab or perform in-house vigor tests. Vigor tests include accelerated aging, controlled deterioration, cold test, cool test, electrolyte leakage, seedling growth rate, and seedling grow-out tests (Table 1). Details for procedures used to conduct vigor tests are found in the Association of Official Seed Analysts' handbook on seed vigor testing (AOSA, 2002).

Stress-related vigor tests

The most common stress-imposed vigor tests include accelerated aging, saturated salts accelerated aging, and controlled deterioration (Bennett et al., 2004; Geneve, 2005). These vigor tests expose seeds to high temperature (35 to 45°C) under a partially imbibed condition for several days prior to conducting a standard germination test. Accelerated aging suspends seeds above water and has been used most successfully with large-seeded crops. However, accelerated aging conditions can be too extreme for the small-seeded crops common to the greenhouse industry. Two alternative tests for small-seeded crops are saturated salts accelerated aging (Jianhua and McDonald, 1996) and controlled deterioration (Powell and Matthews, 1981). These tests are more useful for small-seeded crops because they limit seed hydration during the imposition of heat stress (Geneve, 2005). Saturated salts accelerated aging suspends seeds over a salt solution rather than water as in standard accelerated aging. Controlled deterioration exposes seeds to high temperature (40 or 45°C)

[a]E-mail: rgeneve@uky.edu

for a short duration (24 or 48 h) after the moisture content has been raised to approximately 20%. These tests have proven useful for flower crops like impatiens (*Impatiens walleriana*) and pansy (*Viola × wittrockiana*) (Jianhua and McDonald, 1996; Oakley et al., 2004). These tests require specialized equipment for controlled environmental conditions and may be best conducted by private seed testing labs.

Table 1. Categories of seed vigor arranged according to the germination parameters used to evaluate the seed lot.

Vigor test category	Vigor test	Unit of measure
Biochemical	1. Tetrazolium 2. Electrolyte leakage 3. ATP 4. Ethylene	Tetrazolium uses topology of red stain in embryo Electrolyte leakage uses electrical conductivity (µmhos g^{-1}) ATP is a measure of energy availability Ethylene production is associated with germination and correlates to vigor
Germination percentage	1. Abnormal seedlings 2. Cold test 3. Thermal gradient germination 4. Aging tests a. Controlled deterioration b. Accelerated aging c. Saturated salt accelerated aging d. Natural aging	Percentage of normal seedlings under standard germination conditions; some studies only report radicle protrusion percentage; some tests impose a stress (temperature and/or moisture) prior to standard germination; thermal gradient germination uses variable temperature during germination rather than standard germination conditions; natural aging uses K_i from models for seed deterioration in storage
Germination speed	1. Germination speed 2. Seedling emergence	T_{50}; mean time to germination; expressed as unit of time (days or hours) to reach 50% radicle or seedling emergence
Seedling growth	1. Seedling size 2. Seedling growth rate 3. Vigor index	Linear (cm) or area (mm^2) after a specified time or rate calculated over time (cm or mm^2) per unit time (hour) Vigor index uses growth plus a measure of uniformity

Seedling growth vigor tests

Seedling growth tests include measures of time-to-radicle protrusion (germination speed), seedling growth rate after radicle protrusion, and sorting seedlings into strong or weak growing categories (i.e., grow-out tests).

AOSA (2002) considers germination speed (time-to-radicle protrusion) as an indicator of seed vigor. The most common measures are T_{50}, which determines the time to 50% germination in the population of germinating seeds, and mean time to germination (Maguire, 1962). Similar values can be calculated for the time to seedling emergence in greenhouse studies. Germination speed measurements can be tedious to conduct because they require daily (sometimes hourly) evaluation of germination. Several automated systems have been developed and these have been used by commercial seed labs on a limited basis (Fay et al., 1993; Geneve et al., 2006; Sako et al., 2001).

An alternative to repeated measurements over time is to evaluate seedling size after a predetermined time interval under a controlled environment. Seedling size can be measured by hand or using a vision system such as a flatbed scanner (Oakley et al., 2004). The slant-board method employs germination of seeds on an inclined board so that straight seedlings are obtained that are subsequently hand measured by an analyst (Smith et al., 1973). This test has been used commercially for several small-seeded horticultural crops and is a relatively easy in-house test for growers. An alternative to hand measurements is the use of computer-aided analysis for seedling size calculated from digital images captured by a camera or flatbed scanner. Free software is available on-line for measuring digitally captured seedling length or area and is another alternative for an in-house vigor test as long as seedling growth is under controlled environmental conditions.

Seed producers, brokers and greenhouse growers commonly use seedling emergence grow-outs conducted under greenhouse or growth chamber conditions to evaluate seed vigor. Usable seedlings are evaluated under conditions similar to those used by commercial seedling plug growers. Seedlings are sorted into strong or weak growing categories and additional measures of seedling uniformity can be used to access seed lot vigor.

SEED COATINGS

Presowing seed treatments have become a common practice in the seed industry. Seed treatments are usually applied by seed producers. The objective of a seed coating is to either enhance the potential for germination and seedling emergence or to help mechanical seed sowing. Seed coating uses the same technology and equipment used by the pharmaceutical industry to make medical pills. The major reason to coat seeds is to alter the physical shape and size of the seed as an aid to mechanical sowing. In addition, coatings can act as carriers for various compounds that can enhance germination or seedling establishment, but these are more common for field rather than greenhouse-grown crops. The two most common seed coatings are seed pellets and film coating.

The objective of coating seeds as a pellet is to provide a round, uniform shape and size to small or unevenly shaped seeds in order to aid precision mechanical sowing. Pelletized seeds are tumbled in a pan while binders and inert powders (like clay or diatomaceous earth) form around seeds to provide a uniform, round shape. Traditional pellets can add material to increase seed size by 50 to 100 times. Recently, advanced coating techniques have allowed seed producers to produce thinner pellets (mini-pellets) that increase seed size by only 10 to 25 times.

Film coating uses a thin polymer film to cover the seed (Halmer, 2000). Film coating only adds 1 to 5% to the weight of a seed, but this can still aid in precision sowing by improving flowability and seed pickup during mechanical sowing. Fungicides and beneficial microbes can be added to both pellets and film coatings and is the major benefit to film coating.

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