The Pop Test

A QUICK AID TO ESTIMATE SEED QUALITY

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Figure 1. Hot plate mounted on a propane heater used for conducting "pop" tests at the Aberdeen Plant Materials Center.

ABSTRACT

The seed cleaning and certification process can be shortened by making relatively accurate in-house measurements of seed quality. The USDA Natural Resources Conservation Service Aberdeen Plant Materials Center (PMC) uses a simple procedure known as the Pop Test to estimate seed quality prior to sending seedlots to a laboratory for testing. Pop Tests are conducted simply by heating seeds on a hot plate until they pop. The accuracy of the Pop Test was evaluated by comparing test results with germination and tetrazolium results obtained from a certified laboratory on 14 native species. Results indicate that the Pop Test is a good predictor of seed fill in newer lots of seed. Combined pop and movement responses were well aligned with laboratory results indicating that seed with any movement should be counted as viable. Accuracy of the Pop Test decreases with seed age, because seed embryos die at a quicker rate than seeds lose moisture, retaining the ability to pop even after the seed becomes unviable.

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germination, seed cleaning, seed processing

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Photos by Derek J Tilley

For certified seed production, seed samples must be sent to an accredited seed laboratory for purity, germination, and (or) viability testing. Obtaining the results may take weeks to months depending on the laboratory, time of year, and species being tested. There is also a chance that the laboratory results will indicate viability that is less than the standard required for seed certification, in which case the seed must be re-cleaned and samples resubmitted for further testing. This can be very time consuming and expensive. In order to expedite this process, the staff at the USDA Natural Resources Conservation Service Aberdeen Plant Materials Center (PMC) uses a novel technique that allows them to estimate seed quality during the cleaning process and thus reduce the chance of not meeting seed certification standards.

THE "POP" TEST

Healthy seed contains on average 12 to 15% moisture content at the end of the cleaning process. When placed over sufficient heat, this water is converted to a gas, which exerts tremendous pressure against the seedcoat causing an explosion. In the case of popcorn, as the gasses escape, the inner starch-filled portions of the endosperm fill with air and expand into a tasty treat. A more practical (but less delicious) use of this phenomenon is to estimate seed quality before sending seed off to a laboratory for testing.

The ability of seed to pop is dependent on seed moisture content and the integrity of the seedcoat. Even under good storage conditions, seeds will lose moisture, which means they will lose the ability to pop. In the case of popcorn, for example, optimum popping moisture content is approximately 14%. As the moisture content declines to below approximately 10%, popping performance goes down, and the number of unpopped kernels increases (Hamaker 2010).

Ogle and Cornforth (2000) compared "popping" results of 13 lots of 8 native and introduced grass species with germination tests from the Idaho State Seed Laboratory (Boise) and found a strong correlation between popped seed and overall viability. The trial presented here expands the list of species tested by showing results from 6 native grasses, 3 native grass-like wetland species, 3 native forbs, and 2 native shrubs (Table 1).

MATERIALS AND METHODS

The hot plate used for the popping test is a 1.6-mm (0.0625-in) thick sheet of steel welded with mounting brackets to sit above

TABLE 1

Species included in Pop Test evaluation.

Scientific name	Family	Common name
Grasses		
Elymus glaucus Buckley	Poaceae	Blue wildrye
E. lanceolatus (Scribn. & J.G. Sm.) Gould		Thickspike wheatgrass
E. trachycaulus (Link) Gould ex Shinners		Slender wheatgrass
Leymus cinereus (Scribn. & Merr.) A. Löve		Basin wildrye
L. triticoides (Buckley) Pilg.		Beardless wildrye
Pseudoroegneria spicata (Pursh) A. Löve		Bluebunch wheatgrass
Wetland grass-like species		
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve	Cyperaceae	Hardstem bulrush
S. maritimus (L.) Lye		Alkali bulrush
S. pungens (Vahl) Palla		Common threesquare
Forbs		
Linum lewisii Pursh	Linaceae	Lewis flax
Penstemon eatonii A. Gray	Scrophulariaceae	Firecracker penstemon
P. venustus Douglas ex Lindl.		Venus penstemon
Shrubs		
Atriplex canescens (Pursh) Nutt.	Chenopodiaceae	Fourwing saltbush
Krascheninnikovia lanata (Pursh) A. Meeuse & Smit		Winterfat

a heating element that is fueled with a 13.6-kg (30-lb) propane tank (Figure 1). For best results we set the heater on high. Hot plate temperatures were determined using a Fluke® Ti20 thermal imager (Fluke Corporation, Everett, Washington). Temperatures on the hot plate surface ranged from 126 to 327 °C (260 to 620 °F) at the high setting with most of the plate ranging between 200 and 260 °C (400 and 500 °F). Isolated hot spots of over 315 °C (600 °F) occurred at some of the weld points and along one edge of the hot plate.

We observed popping reactions of 8 replications of 25 seeds for each lot tested (Table 1). Seed was placed in the 200 to 260 °C (400 to 500 °F) portion of the plate for up to 15 s. Results were divided into 4 categories: 1) seeds that popped explosively and audibly; 2) seeds that rolled or moved but did not pop; 3) a combined response of seed that showed any movement including popping and rolling; and 4) no response. Means obtained from the Pop Test were used to create 90 and 95% confidence intervals (CI) and were compared with viability results from the Idaho State Seed Laboratory (Boise). Viability of grass-like wetland species, *Penstemon* species, and fourwing saltbush (see tables for nomenclature) was determined using tetrazolium (TZ) tests. All other species were tested using standard germination protocols.

To better understand the amount of damage a seed could sustain and still pop, we also tested cut portions of seed of meadow brome (*Bromus biebersteinii* Roem. Schult. [Poaceae] not included on tables) and observed responses to heat. Three sections of seed were tested: seed bisected along the rachilla (lateral halves), apical halves, and distal halves. Ten seeds of each portion were tested and compared to a non-cut control.

TABLE 2

Pop Test results for grasses.

Species	Seedlot	Seed age (y)	Laboratory viability (%)	Popped (%) and percentage points different from laboratory	Combined (%) and percentage points different from laboratory
Elymus glaucus	ELGL-07a	3	86	47 (–39)	96 (+10)
	ELGL-07b	3	57	21 (–36)	59 (+2)
E. lanceolatus	ELLAL-00	10	93	40 (–53)	85 (–8)*
	ELLAL-02	8	89	35 (–54)	89 (=)**
	ELLAL-07a	3	95	27 (–68)	91 (–4)**
	ELLAL-07b	3	95	63 (–32)	88 (–7)*
	ELLAL-09	1	15	9 (–5)*	20 (+5)*
E. trachycaulus	ELTR7-06	4	90	42 (–48)	96 (+6)
	ELTR7-07	3	94	34 (–60)	94 (=)**
	ELTR7-08	2	97	41 (–56)	98 (+1)**
Leymus cinereus	LECI4-00a	10	90	41 (–49)	85 (–5)*
	LECI4-00b	10	90	26 (–64)	90 (=)**
	LECI4-02	8	84	47 (–37)	79 (–5)**
	LECI4-03	7	83	23 (–60)	84 (+1)**
L. triticoidies	LETR5-81	19	0	36 (+36)	74 (+74)
	LETR5-06	4	63	24 (–39)	67 (+4)**
Pseudoroegneria spicata	PSSPS-81	19	0	21 (+21)	51 (+51)
	PSSPS-02	8	90	39 (–29)	97 (+7)*
	PSSPS-05	5	90	14 (–76)	92 (+2)**
	PSSPS-06	4	92	65 (–27)	89 (–3)**
	PSSPS-08	2	92	25 (-67)	95 (+3)*

* Laboratory results were within 90% CI of PMC results.

** Laboratory results were within 95% CI of PMC results.

RESULTS

Grasses

Viability results for 16 of 21 grass seedlots tested by the laboratory were within the 90% CI we calculated for our combined response, while 10 of 21 were within the 95% CI (Table 2). The popping alone response tended to be significantly lower than laboratory results with only one seedlot being within the 90% CI.

Wetland Grass-like Monocots

All pop and combined response results from the grass-like wetland species from our test and the seed laboratory were tightly correlated (Table 3). Laboratory viability of the 3 wetland grass-like monocots ranged from 85 to 94%, whereas our Pop Test and the combined response ranged from 82 to 93%; most laboratory results were within the 95% CI of our results (Table 3).

Forbs

Laboratory results of one of the 2 lots of Lewis flax (LILE3-04a) fell within the 95% CI of the combined response category (Table 4), but popping alone significantly underestimated viability for both lots. Popping and combined categories underestimated viability in the tested lots of firecracker and Venus penstemon.

Shrubs

Winterfat seed did not react as visibly to heat as some of the other species tested, but careful observation did reveal swelling, rolling, and occasional popping (Table 5). Laboratory results fell within the 95% CI for the combined pop and movement category. Popping alone corresponded poorly with laboratory viability test results. No response was detected from any seed of fourwing saltbush.

Seed Damage

Damage to the seedcoat significantly reduced the percentage of popping responses in the seed observed (Table 6). Combined responses of the lateral and apical portions were similar to those of the non-cut control group, while the distal halves showed a slight decrease in overall response.

DISCUSSION

Seed of most of the species tested will pop if it has sufficient moisture. We did not evaluate moisture content in this trial, however, so no conclusions can be inferred regarding necessary

TABLE 3

Pop Test results for wetland grass-like species.

Species	Seedlot	Seed age (y)	Laboratory viability (%)	Popped (%) and percentage points different from laboratory	Combined (%) and percentage points different from laboratory
Schoenoplectus acutus	SCACA-04	6	85	90 (+5)**	93 (+8)
S. maritimus	SCMA8-04	6	94	88 (–6)**	89 (–5)**
S. pungens	SCPU10-05	5	89	82 (–7)*	91 (+2)**

* Laboratory results were within 90% CI of PMC results.
** Laboratory results were within 95% CI of PMC results.

TABLE 4

Pop Test results for forbs.

Species	Seedlot	Seed age (y)	Laboratory viability (%)	Popped (%) and percentage points different from laboratory	Combined (%) and percentage points different from laboratory
Linum lewisii	LILE3-04a	6	84	34 (–50)	79 (–5)**
	LILE3-04b	6	85	23 (–62)	74 (–11)*
Penstemon eatonii	PEEA-05	5	94	28 (–66)	51 (–43)
P. venustus	PEVE-06	4	96	43 (–53)	69 (–27)

* Laboratory results were within 90% CI of PMC results.
** Laboratory results were within 95% CI of PMC results.

TABLE 5

Pop Test results for shrubs.

Species	Seedlot	Seed age (y)	Laboratory viability (%)	Popped (%) and percentage points different from laboratory	Combined (%) and percentage points different from laboratory
Atriplex canescens	ATCA2-08	2	35	0 (–350	0 (–35)
Krascheninnikovia lanata	KRLA2-06	4	83	23 (–60)	77 (–6)**

* Laboratory results were within 90% CI of PMC results.

** Laboratory results were within 95% CI of PMC results.

TABLE 6

Results of seed damage test.

Tested section	Popped (%)	Movement (%)	No response (%)
Lateral	0	100	0
Apical	30	60	10
Distal	40	20	40
Non-cut control	70	20	10

moisture levels required for popping for each species. The evaluation of cut seed and very old seed (lots LETR5-81 and PSSPS-81) indicates that seed will have some physical reaction to heat, whether viable or not, yet damage to the seedcoat reduces popping. Popping, therefore, may indicate good seed fill but not necessarily the presence of a healthy embryo. In fresh seed, the absence of a pop or movement often indicates an empty hull or floret. In older seed, the decrease of response to heat may indicate loss of moisture, degeneration of endosperm, or a breakdown in the seedcoat.

Audible popping was highly variable in the species tested, as was evidenced by larger confidence intervals, and significantly underestimated viability in almost every seedlot tested. Combined pop and movement responses, however, were well aligned with laboratory results. Laboratory test results fell within 95% confidence intervals 15 of 30 times, and our results were within 10% of laboratory results 25 of 30 times. Our results indicate that seed with any movement should be counted as viable, and not just those with a distinctive pop.

Seed of some species pop and visibly produce a popcorn-like puff, such as in hardstem bulrush (Figure 2). Others pop but the starchy puff is difficult to see. Many grasses fall into the latter category because the caryopsis is enclosed in the lemma and palea. Other species, such as Lewis flax, pop very quickly and multiple times. Some species are too small to accurately observe popping; the smaller the seed, the more quickly the popping occurs upon touching the hot plate, making it difficult to obtain an accurate count. *Juncus*, *Calamagrostis*, and *Achillea,* for example, are perhaps better evaluated using a small amount of seed and estimating the percentage that popped instead of conducting an actual count.

Several species evaluated either do not pop or popped erratically. Fourwing saltbush could not be induced to pop or otherwise react to the hot plate, most likely because the outer walls of the seed absorb the heat and burn rather than allowing the seed to pop. Indian ricegrass (*Achnatherum hymenoides* (Roem. & Schult.) Barkworth [Poaceae]) (data not shown) also pops inconsistently, and the round shape of the seeds makes it difficult to keep them from rolling off the hot plate. The 2 penstemon species evaluated in this trial popped, but results were significantly lower than viability obtained in laboratory tests. Several other forb species have been successfully popped at the PMC but were not evaluated in this study, including Douglas' dustymaiden (*Chaenactis douglasii* (Hook.) Hook. & Arn. [Asteraceae]), parsnipflower buckwheat (*Eriogonum heracleoides* Nutt. [Polygonaceae]), sulphur-flower buckwheat (*E. umbellatum* Torr. [Polygonaceae]), lobeleaf groundsel (*Packera multilobata* (Torr. & A. Gray ex A. Gray) W.A. Weber & A. Löve [Asteraceae]), silverleaf phacelia (*Phacelia hastata* Douglas ex

Figure 2. Popped seed of hardstem bulrush revealing popcorn-like puff of starchy endosperm.

Lehm. [Hydrophyllaceae]), lambstongue ragwort (*Senecio integerrimus* Nutt. [Asteraceae]), and gooseberryleaf globemallow (*Sphaeralcea grossulariifolia* (Hook. & Arn.) Rydb. [Malvaceae]).

Older Seed

Even under optimal conditions, seed ages over time, gradually loses vigor, and eventually dies (Justice and Bass 1978). As seed ages in storage, the moisture content declines in dry conditions and seed loses the ability to pop. Most of us have witnessed this as the increased number of unpopped kernels found when cooking with older popcorn. Our results show a decreased overall response to heat for older seed compared to that of newer seed; however, the popping and combined responses were significantly greater than actual viability. Bluebunch wheatgrass seed ranging from 2 to 8 y old had an average popping response of 35% and a combined response of 88%, with 91% viability, while the 29-y-old seedlot had a popping response of 21%, a combined response of 50%, and 0% germination (Table 2). Similarly, a 29-y-old lot of beardless wildrye seed had a popping response of 36%, combined response of 74%, and 0% germination.

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CONCLUSIONS

Our tests showed a reasonably close correlation (generally within 10%) between seed viability and response to heat for newer lots of seed, but a significant overestimation of quality in older seedlots. Our tests also revealed species for which the Pop Test was ineffective. The Pop Test is not completely reliable and will never replace actual germination or even TZ testing, but it can be used by seed producers and end users to provide a general indication of seed quality and thereby reduce processing time.

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