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Quick Methods to Estimate Seed Quality

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Abstract
Waiting for laboratory germination results to determine if seed lots require additional cleaning can be time consuming and expensive. The process can be shortened by making relatively accurate in-house measurements of seed quality.

The Aberdeen Plant Materials Center (PMC) uses two simple procedures to estimate seed quality prior to sending seeds lots to a lab for testing, the pop test and historic bushel weights. A series of tests were conducted at the PMC to evaluate the accuracy of the pop test when compared with germination and tetrazolium results obtained from a certified lab. Popping reactions were observed and divided into three categories, 1) seeds that popped explosively and audibly, 2) seeds that rolled or moved but did not pop, and 3) no response. Means obtained from the pop test were used to create 90 and 95% confidence intervals (CI), and compared with results from the Idaho State Seed Lab. Our results indicate that the pop test is a good predictor of seed fill in newer lots of seed of many species tested. Combined pop and movement responses were well aligned with lab results. Lab tests fell within the 95% CI 15 of 30 times, and the 90% CI 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. Accuracy decreases with seed age, because seed embryos die at a quicker rate than seeds lose moisture.

This paper also discusses the use of bushel weights to estimate seed quality and provides tables of historic seed bushel weights of several native range and pasture grass, forb and shrub species.

Nomenclature: USDA-NRCS (2010)

Introduction

For certified seed production, seed samples must be sent to an accredited seed laboratory for purity, germination, and/or viability testing. Getting these results back may take weeks to months depending on the lab, time of year, and species being tested. There is also a chance that the lab results will indicate viability 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 Aberdeen Plant Materials Center (PMC) uses a novel technique that allow them to estimate seed quality during the cleaning process and thus reduce the chance of not meeting seed certification standards.

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

The "Pop" Test

Healthy seed contains on average 12 to 15 percent 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 seed coat 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 lab for testing.

The ability of seed to pop is dependent upon seed moisture content and the integrity of the seed coat. Even under good storage conditions, seeds lose this ability as the seed slowly loses moisture. In the case of popcorn, for example, optimum popping moisture content is approximately 14 percent. As the moisture content declines to below approximately 10 percent, popping performance goes down, and the number of unpopped kernels increases (Hamaker, 2010).

Ogle and Cornforth (2000) compared "popping" results of 13 lots of eight native and introduced grass species with germination tests from the State Seed Laboratory 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) sheet of steel welded with mounting brackets to sit over a heating element which 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. 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 lying 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.

Table 1. Species included in pop test evaluation.

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

We observed popping reactions of eight replications of 25 seeds for each lot tested. Seed was placed in the 200 to 260° C (400 and 500° F) portion of the plate for up to 15 seconds. Results were divided into three categories, 1) seeds that popped explosively and audibly, 2) seeds that rolled or moved but did not pop, and 3) no response. Means obtained from the pop test were used to create 90 and 95% confidence intervals (CI), and compared with results from the Idaho State Seed Lab. Viability of grass-like wetland species, *Penstemon* species and fourwing saltbush was determined using tetrazolium (TZ) tests. All other species were tested using standard germination protocols.

Seed Damage

In order 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. [excluded] [Poaceae]) and observed responses to heat. Three sections of seed were tested, 1) seeds bisected along the rachilla (lateral halves), and seed cross-cut at mid-length providing 2) apical and 3) distal halves. Ten seeds of each portion were tested and compared to a non-cut control.

Results

Grasses

Sixteen out of 21 grass seed lots tested were within the 90% CI for the combined response, while 10 of 21 were within the 95% CI (table 2). The popping alone response tended to be significantly lower than lab results with only one seed lot being within the 90% CI.

Table 2. Pop test results for grasses.

Species	Seed Lot	Seed Age	% Lab Viability	% Popped (diff. from lab)	% Combined (diff from lab)
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)*

* Test results were within 90% CI of lab results.
** Test results were within 95% CI of lab results.

Wetland Grass-like Monocots

All results from the grass-like wetland species were tightly correlated (table 3). Results from popping alone of hardstem bulrush (SCACA-04) were within the 95% CI, while the combined response slightly overestimated viability. Lab results of alkali bulrush (SCMA8-04) and common threesquare (SCPU10-05) fell within the combined response 95% CI. Popping alone slightly underestimated lab results in common threesquare but was within the 95% CI for alkali bulrush.

Table 3. Pop test results for wetland grass-like species.

Species	Seed Lot	Seed Age	% Lab Viability	% Popped (diff. from lab)	% Combined (diff from lab)
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)**

* Test results were within 90% CI of lab results.
** Test results were within 95% CI of lab results.

Forbs

Lab results of 1 of the 2 lots of Lewis flax (LILE3-04a) fell within the 95% CI of the combined response category (table 4). Popping alone significantly underestimated viability in both cases. Both popping and combined categories underestimated viability in the tested lots of firecracker and Venus penstemon.

Table 4. Pop test results for forbs.

Species	Seed Lot	Seed Age	% Lab Viability	% Popped (diff. from lab)	% Combined (diff from lab)
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)

* Test results were within 90% CI of lab results.
** Test results were within 95% CI of lab results.

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). The combined pop and movement category correlated well with lab test results falling within the 95% CI. Popping alone did not correspond with lab viability test results. No response was detected from any seed of fourwing saltbush.

Table 5. Pop test results for shrubs.

Species	Seed Lot	Seed Age	% Lab Viability	% Popped (diff. from lab)	% Combined (diff from lab)
Krascheninnikovia lanata	KRLA2-06	4	83	23 (-60)	77 (-6)**
Atriplex canescens	ATCA2-08	2	35	0 (-350	0 (-35)

* Test results were within 90% CI of lab results.
** Test results were within 95% CI of lab results.

Seed Damage

Damage to the seed coat significantly reduced the percentage of popping responses in the seeds 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.

Table 6. Results of seed damage test.

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

Discussion

Seed of most of the species tested will pop if they have sufficient moisture. We did not evaluate moisture content in this trial, however, so no conclusions can be inferred regarding necessary 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 with proper moisture content, seed will have some physical reaction to heat, whether viable or not, yet damage to the seed coat reduces popping. Popping, therefore, may indicate good seed fill, 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 seed coat.

Audible popping was highly variable in the species tested, as was evidenced by larger confidence intervals, and significantly underestimated viability in almost every seed lot tested. Combined pop and movement responses, however, were well aligned with lab results. Lab tests fell within 95 percent confidence intervals 15 of 30 times, and was within 10% of lab 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.

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

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 percent 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 hynmenoides* (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 lab tests. Several other forb species have been successfully popped at the PMC but were not evaluated in this study. These include: Douglas' dustymaiden (*Chaenactis* *douglasii* (Hook.) Hook. & Arn. [Asteraceae]), parsnipflower buckwheat (*Eriogonum heracleoides* Nutt. [Polygonaceae], sulphurflower 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 Lehm. [Hydrophyllaceae]), lambstongue ragwort (*Senecio integerrimus* Nutt. [Asteraceae]), and gooseberryleaf globemallow (*Sphaeralcea grossulariifolia* (Hook. & Arn.) Rydb. [Malvaceae]).

Older Seed

Even under optimal conditions, seeds age over time, gradually lose vigor and eventually die (Justice and Bass, 1978). As seed ages in storage, the moisture content declines in dry conditions, and seeds lose the ability to pop. Most of us have witnessed this as the increased number of unpopped kernels found in 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 two to eight years old had an average popping response of 34.7% and combined response of 88.0%, and 91% viability, while the 29 year old seed lot had a popping response of 21.0%, a combined response of 50.5% and 0% germination (table 2). Similarly, a 29 year old lot of beardless wildrye seed had a popping response of 36.0%, combined response of 73.5%, and 0% germination.

Conclusions

Our tests showed a reasonably close correlation (generally within 10%) between seed quality and response to heat for newer lots of seed, but a significant overestimation quality in older seed lots. Our tests also revealed several species for which the pop test was ineffective. The pop test is not one hundred percent 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 reduce processing time.

Bushel Weights

People have been using bushel weights to facilitate grain trade for centuries. Knowing the weight of a given volume of grain allows the buyer to have some assurance of seed quality and especially moisture content. The Aberdeen PMC tracks bushel weights of seed lots during the cleaning process to estimate seed purity and fill. Clean lots of seed with high viability and moisture content are heavier per volume than seed with poor viability and purity. If a sampled lot has a lower bushel weight than historical records, then the lot may require additional cleaning with greater air flow to blow off the lighter, poor-quality seed.

The PMC uses a Fairbanks-Morse bushel equivalent scale which is pre-calibrated to provide bushel weights based on a 10 cm x 11.7 cm (1075 cm³) sample (figure 3). Any volume of test sample can be used with a simple conversion however. A measuring cup makes a good sample size. The cup should be loosely filled and the excess seed smoothed off with a ruler or other flat instrument. There are approximately 149 cups per bushel and 454 grams per pound, so the conversion equation goes as follows:

$$\text{Lbs per bushel} = \frac{\text{Grams per cup X 149}}{454}$$

For example: if one cup of seed weighed 67 g, one would multiply that by 149 and divide by 454 to get a bushel weight of 22 lbs/bushel.

Figure 3. Bushel equivalent scale at Aberdeen PMC.

The following tables 7-9 provide bushel weights from many of the commonly used range and pasture species used in the Intermountain West and beyond. The reported values have been gathered over many years by the staff at the Aberdeen PMC and others and represent averages obtained after examining multiple seed lots.

Table 7. Bushel weights of common native range and pasture grasses.

Scientific Name	Common Name	Release Name	Pounds per Bushel
Achnatherum hymenoides	Indian ricegrass	'Nezpar'	56.5
		'Rimrock'	51.4
A. thurberianum	Thurbers needlegrass	Common	25.6
Agrostis gigantea	Redtop bentgrass	Multiple turfgrasses	14.0
Bromus marginatus	Mountain brome	'Bromar'	23.1
		Garnet Germplasm	23.0
Calamovilfa longifolia	Prairie sandreed	'Goshen'	43.7
Elymus canadensis	Canada wildrye	'Mandan'	25.3
E. elymoides	Bottlebrush squirreltail	Fish Creek Germplasm	22.1
		Sand Hollow Germplasm	25.2
		Toe Jam Creek Germplasm	21.1
		Wapiti Germplasm	27.6
E. lanceolatus	Streambank wheatgrass	'Sodar'	21.1
	Thickspike wheatgrass	'Bannock'	16.8
		'Critana'	18.5
		'Schwendimar'	15.0
E. trachycaulus	Slender wheatgrass	'First Strike'	21.0
		'Pryor'	20.2
		'San Luis'	22.7
E. wawawaiensis	Snake River wheatgrass	'Discovery'	25.8
		'Secar'	20.3
Festuca arizionica	Arizona fescue	'Redondo'	22.0
Leymus cinereus	Basin wildrye	'Continental'	16.8
		'Magnar'	18.5
		'Trailhead'	17.5
		Washoe Germplasm	18.5
Nassella viridula	Green needlegrass	Cucharas Germplasm	41.5
		'Lodorm'	48.0
Panicum virgatum	Switchgrass	'Dakotah'	59.0
	Switchgrass	'Forestburg'	50.0
Pascopyrum smithii	Western wheatgrass	'Arriba'	20.0
		'Recovery'	17.7
		'Rodan'	18.7
		'Rosana'	19.5
Poa canbyi	Canby bluegrass	'Canbar'	18.8
Poa compressa	Canada bluegrass	Foothills Germplasm	20.9
Poa nevadensis	Big bluegrass	'Opportunity'	32.5
		'Sherman	17.9
Poa secunda	Sandberg bluegrass	High Plains Germplasm	15.7
		Mountain Home Germ.	19.3
		Reliable Germplasm	18.0
Pseudoroegneria spicata	Beardless wheatgrass	'Whitmar'	19.5
	Bluebunch wheatgrass	Anatone Germplasm	21.7
		'Goldar'	30.0
		'P7'	20.7

Table 8. Bushel weights of common rangeland forbs.

Scientific name	Common Name	Release Name	Pounds per Bushel
Achillea millefolium	Yarrow	Eagle Germplasm	37.0
		Great Northern Germplasm	20.6
		Yakima Germplasm	36.0
Chaenactis douglasii	Douglas' dustymaiden	Common	4.0
Dalea candida	Prairie Clover, White	Antelope Germplasm	63.8
Hedysarum boreale	Sweetvetch, Utah	'Timp'	50.0
Linum lewisii	Flax, Lewis	Maple Grove Germplasm	38.8
Machaeranthera canescens	Tansyaster, Hoary	Common	3.0
Penstemon eatonii	Penstemon, Firecracker	Richfield Germplasm	34.8
Penstemon palmeri	Penstemon, Palmer	'Cedar'	53.9
Penstemon strictus	Penstemon, Rocky Mountain	'Bandera'	27.5
Penstemon venustus	Penstemon, Venus	Clearwater Germplasm	30.6
Phacelia hastata	Phacelia, Silverleaf	Common	59.1
Ratibida columnifera	Coneflower, Prairie	Stillwater Germplasm	33.1
Sphaeralcea sp.	Globemallow	Common	23.5

Table 9. Bushel weights of common rangeland shrubs.

Scientific Name	Common Name	Release Name	Pounds per Bushel
Artemisia tridentata ssp. *wyomingensis*	Sagebrush, Wyoming Big	Common	10.4
Atriplex canescens	Saltbush, Fourwing	Snake River Plains Germ.	25.4
		'Wytana'	22.7
Atriplex confertifolia	Shadscale	Common	20.9
Krascheninnikovia lanata	Winterfat	Northern Cold Desert Germplasm	29.1
		Open Range Germplasm	33.1
Purshia tridentata	Bitterbrush, Antelope	Maybell Source	32.5

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