

The **viabilitymetrics** package: A brief introduction

J. Aravind, S. Vimala Devi, J. Radhamani and Kalyani Srinivasan

ICAR-National Bureau of Plant Genetic Resources, New Delhi

2018-03-30

Contents

Overview	1
Installation	1
Viability constants	1
Citing viabilitymetrics	6
Session Info	6
References	7

Overview

Installation

The package can be installed using the following functions:

```
# Install from CRAN
install.packages('viabilitymetrics', dependencies=TRUE)

# Install development version from Github
devtools::install_github("aravind-j/viabilitymetrics")
```

Then the package can be loaded using the function

```
library(viabilitymetrics)
```

Viability constants

Index	Species	K _E	C _W	C _H	C _Q	Reference
1	<i>Abelmoschus esculentus</i> *	6.659	2.448	0.0329	0.000478	Daniel et al. (2013)
2	<i>Acer platanoides</i> *	7.22	4.23	0.0329	0.000478	Dickie et al. (1991)
3	<i>Agastache rugosa</i>	6.93	4.255	0.0329	0.00048	Lee et al. (2017)
4	<i>Agathus australis</i>	6.36	3.64	0.0329	0.000478	Dickie and Smith (1995)
5	<i>Allium cepa</i>	6.975	3.47	0.04	0.000428	Ellis and Roberts (1981)
6	<i>Allium cepa</i> *	9.083	5.81	0.0329	0.000478	Ellis et al. (1990)
7	<i>Arabidopsis thaliana</i>	8.35	5.15	0.0563	8.39e-05	Hay et al. (2003)
8	<i>Arachis hypogaea</i>	6.718	4.089	0.0329	0.000478	Ellis et al. (1990)
9	<i>Arachis hypogaea</i>	6.177	3.426	0.0304	0.000453	Usberti and Gomes (1998)

Index	Species	K _E	C _W	C _H	C _Q	Reference
10	<i>Araucaria columnaris</i>	5.66	2.68	0.033	0.000478	Tompsett (1984); Tompsett (1992)
11	<i>Araucaria cunninghamii</i>	7.49	3.73	0.033	0.000478	Tompsett (1992)
12	<i>Balfourodendron riedelianum</i>	2.867	9.77e-13	1.344e- 12	1.165e- 13	Ignácio (2013)
13	<i>Beta vulgaris</i>	9.373	5.152	0.0372	0.000467	Ellis and Hong (2007)
14	<i>Beta vulgaris</i> *	8.943	4.723	0.0329	0.000478	Ellis et al. (1990)
15	<i>Borago officinalis</i>	6.748	2.42	0.0665	0.000478	Far et al. (2010)
16	<i>Brachiaria brizantha</i> (Intact seed)	6.488	4.48	0.0475	0.001292	Usberti (2007)
17	<i>Brachiaria brizantha</i> (Scarified seed)	8.795	4.852	0.02114	0.000733	Usberti (2007)
18	<i>Brassica juncea</i> *	7.768	4.56	0.0329	0.000478	Ellis et al. (1989)
19	<i>Brassica napus</i> *	7.718	4.54	0.0329	0.000478	Ellis et al. (1989)
20	<i>Brassica napus</i>	5.654	2.5	0.04387	1.438e- 05	Alivand et al. (2013)
21	<i>Capsicum annum</i> *	7.767	4.67	0.0329	0.000478	Demir et al. (2009)
22	<i>Celosia argentea</i> *	4.957	1.188	0.0329	0.000478	Daniel et al. (2012)
23	<i>Chenopodium quinoa</i> *	8.58	5.02	0.0329	0.000478	Ellis et al. (1988)
24	<i>Cicer arietinum</i>	8.901	4.847	0.0329	0.000478	Ellis et al. (1982); Dickie et al. (1990)
25	<i>Cicer arietinum</i>	8.502	4.602	0.0295	0.000491	Ellis (1988)
26	<i>Citrullus lanatus</i> *	4.86	1.59	0.0329	0.000478	Demir et al. (2011)
27	<i>Cucumis melo</i> *	6.11	2.59	0.0329	0.000478	Demir et al. (2011)
28	<i>Cucumis melo</i>	7.299	3.707	0.0367	0.000473	Kuo (1991)
29	<i>Cucumis sativus</i> *	5.35	2.03	0.0329	0.000478	Demir et al. (2011)
30	<i>Cucurbita pepo</i>	6.913	3.604	0.04	4e-04	Hong et al. (1996)
31	<i>Cucurbita pepo</i> subsp. <i>pepo</i> convar. <i>pepo</i> var. <i>styriaca</i>	3.402	3.215	0.131	0.00264	Far et al. (2010)
32	<i>Dactylis glomerata</i>	4.715	0.554	0.03	2e-04	Reza (2014a)
33	<i>Dalbergia nigra</i>	5.199	4.524	0.08175	0.001641	Chaves and Usberti (2004)
34	<i>Delphinium ambiguum</i>	7.67	3.12	0.04	4e-04	Hong et al. (1996)
35	<i>Descurainia sophia</i>	4	0.179	0.03	0.000445	Reza (2014b)
36	<i>Digitalis purpurea</i> *	7.49	5.61	0.0329	0.000478	Hong et al. (1996)
37	<i>Dimorphandra mollis</i>	6.282	3.838	0.05405	0.001316	Chaves and Usberti (2004)
38	<i>Dioscorea dumetorum</i>	5.859	-3.06	-7e-04	-7e-04	Daniel et al. (2003)
39	<i>Dioscorea togoensis</i>	4.505	-1.646	-0.02	-0.00011	Daniel et al. (2003)
40	<i>Dipterocarpus alatus</i>	5.92	2.69	0.033	0.000478	Tompsett (1992)
41	<i>Dipterocarpus intricatus</i>	6.18	2.77	0.033	0.000478	Tompsett (1992)

Index	Species	K _E	C _W	C _H	C _Q	Reference
42	<i>Dracocephalum moldavica</i>	3.837	0.2	0.03	2e-04	Reza (2014b)
43	<i>Eleusine coracana</i>	7.88	4.181	0.0254	0.000489	Ellis and Hong (2007)
44	<i>Eleusine coracana</i> *	9.508	5.08	0.0329	0.000478	Ellis et al. (1989)
45	<i>Elytrigia elongate</i>	6	1.642	0.03	2e-04	Reza (2014a)
46	<i>Entandophragma angolense</i>	4.6	2.21	0.033	0.000478	Tompsett (1992)
47	<i>Eragrostis tef</i> *	10.1	6.01	0.0329	0.000478	Ellis et al. (1989)
48	<i>Eragrostis tef</i> cv. Muri	9.727	5.185	0.0329	0.00054	Zewdie and Ellis (1991)
49	<i>Eragrostis tef</i> cvs.	9.927	5.185	0.0329	0.00054	Zewdie and Ellis (1991)
50	<i>Eruca sativa</i>	4.33	0.4574	0.03	0.000304	Reza (2014b)
51	<i>Eucalyptus bussei</i> *	7.3	3.96	0.0329	0.000478	Muthoka et al. (2009)
52	<i>Eucalyptus erythrocorys</i>	8.81	4.97	0.0412	0.000379	Crawford et al. (2013)
53	<i>Eucalyptus grandis</i>	9.661	6.467	0.03498	0.000233	Fantinatti and Usberti (2007)
54	<i>Eucalyptus heterochroma</i> *	8.9	6.89	0.0329	0.000478	Muthoka et al. (2009)
55	<i>Eucalyptus heterophylla</i> *	7.4	4.36	0.0329	0.000478	Muthoka et al. (2009)
56	<i>Eucalyptus pseudoburuana</i> *	10.1	7.81	0.0329	0.000478	Muthoka et al. (2009)
57	<i>Eucalyptus quinquecostata</i> *	10.2	8.09	0.0329	0.000478	Muthoka et al. (2009)
58	<i>Festuca ovina</i>	4.366	0.5	0.03	2e-04	Reza (2014a)
59	<i>Glycine max</i>	7.525	4.086	0.0329	0.000478	Ellis et al. (1982); Dickie et al. (1990)
60	<i>Glycine max</i>	7.292	3.996	0.0295	0.000491	Ellis (1988)
61	<i>Gossypium hirsutum</i>	9.24	5.19	0.03965	0.000426	Usberti et al. (2006)
62	<i>Guizotia abyssinica</i> *	7.578	4.78	0.0329	0.000478	Ellis et al. (1989)
63	<i>Guizotia abyssinica</i>	7.494	4.257	0.0372	0.00048	Zewdie and Ellis (1991)
64	<i>Gypsophila elegans</i>	9.6	5.36	0.04	4e-04	Hong et al. (1996)
65	<i>Helianthus annuus</i> *	6.74	4.16	0.0329	0.000478	Ellis et al. (1988)
66	<i>Hordeum vulgare</i>	9.144	5.342	0.0329	0.000478	Ellis and Roberts (1980); Dickie et al. (1990)
67	<i>Khaya senegalensis</i>	4.76	2.15	0.033	0.000478	Tompsett (1992)
68	<i>Lactuca sativa</i>	7.938	5.25	0.0329	0.000478	Ellis et al. (1989)
69	<i>Lactuca sativa</i> *	6.895	4.2	0.0329	0.000478	Kraak and Vos (1987); Dickie et al. (1990)
70	<i>Lallemantia royleana</i>	4.725	2.324	0.02544	1.068e-05	Baladi and Balouchi (2016)
71	<i>Linum usitatissimum</i> *	7.76	4.86	0.0329	0.000478	Ellis et al. (1988)
72	<i>Linum usitatissimum</i> cv. Norman	5.201	2.59	0.03613	1.5e-05	Balouchi et al. (2017)
73	<i>Linum usitatissimum</i> cv. Urmia	4.474	2.185	0.01467	0.000161	Balouchi et al. (2017)

Index	Species	K _E	C _W	C _H	C _Q	Reference
74	<i>Liquidambar styraciflua</i>	6.553	3.033	0.0081	0.00151	Bonner (1994)
75	<i>Liquidambar styraciflua</i>	6.385	2.706	0.0306	0.000967	Bonner (1994)
76	<i>Lupinus polyphyllus</i>	6.217	2.761	0.04	4e-04	Dickie and Bowyer (1985)
77	<i>Lycopersicon esculentum</i>	6.502	3.181	0.0324	0.000431	Kruse et al. (2005)
78	<i>Lycopersicon esculentum</i>	4.544	2.683	-0.05018	0.001266	Sinício et al. (2009)
79	<i>Malus domestica</i>	7.316	4.119	0.04	0.00042	Dickie (1988)
80	<i>Melilotus officinalis</i>	4.21	0.2	0.03	2e-04	Reza (2014b)
81	<i>Nigella sativa</i>	4.97	1.253	0.0516	0.000478	Far et al. (2010)
82	<i>Orobanche aegyptiaca</i>	6.434	0.0356	0.066	1e-05	Kebreab and Murdoch (1999)
83	<i>Orobanche crenata</i>	6.447	0.0356	0.066	1e-05	Kebreab and Murdoch (1999)
84	<i>Orobanche minor</i>	6.126	0.0356	0.066	1e-05	Kebreab and Murdoch (1999)
85	<i>Oryza glaberrima</i>	9.406	5.043	0.0375	0.000471	Ellis and Hong (2007)
86	<i>Oryza glaberrima</i> *	6.871	5.51	0.0329	0.000478	Bam et al. (2008)
87	<i>Oryza sativa</i>	8.242	4.345	0.0307	0.000501	Ellis and Hong (2007)
88	<i>Oryza sativa</i> *	8.668	5.03	0.0329	0.000478	Ellis et al. (1989)
89	<i>Oryza sativa</i> ssp. <i>indica</i> *	8.81	4.904	0.0329	0.000478	Ellis et al. (1992)
90	<i>Oryza sativa</i> ssp. <i>japonica</i> *	8.416	4.904	0.0329	0.000478	Ellis et al. (1992)
91	<i>Oryza sativa</i> ssp. <i>japonica</i> *	6.628	5.51	0.0329	0.000478	Bam et al. (2008)
92	<i>Oryza sativa</i> ssp. <i>javanica</i> *	8.736	4.904	0.0329	0.000478	Ellis et al. (1992)
93	<i>Papaver nudicaule</i>	6.838	4.101	0.027	0.000313	Belletti et al. (1991)
94	<i>Paspalum scrobiculatum</i>	8.066	4.449	0.0266	0.000526	Ellis and Hong (2007)
95	<i>Pennisetum glaucum</i> *	8.728	4.86	0.0329	0.000478	Ellis et al. (1989)
96	<i>Pennisetum purpureum</i> Ã— <i>P. glaucum</i> (Cutting type)	7.735	4.658	0.01969	0.000403	Pozitano and Usberti (2009)
97	<i>Pennisetum purpureum</i> Ã— <i>P. glaucum</i> (Grazing type)	8.825	4.522	0.03655	3e-04	Pozitano and Usberti (2009)
98	<i>Pennisetum purpureum</i> Ã— <i>P. glaucum</i> (Original type)	8.417	5.037	0.02309	0.000436	Pozitano and Usberti (2009)
99	<i>Pennisetum typhoides</i>	8.442	5.035	0.025	0.000443	Ellis and Hong (2007)
100	<i>Phaseolus vulgaris</i> *	9.09	4.761	0.0329	0.000478	Ellis et al. (1990)
101	<i>Phaseolus vulgaris</i>	9.08	5.2	0.0057	0.00079	Wilson and McDonald (1989)
102	<i>Phleum pratense</i>	9.571	5.262	0.04	4e-04	Hong et al. (1996)

Index	Species	K _E	C _W	C _H	C _Q	Reference
103	<i>Phleum pratense</i> cv. Erecta*	8.678	4.75	0.0329	0.000478	Ellis et al. (1989)
104	<i>Phleum pratense</i> cv. S325*	8.138	4.75	0.0329	0.000478	Ellis et al. (1989)
105	<i>Pinus elliottii</i>	5.588	1.449	0.0326	0.00101	Bonner (1994)
106	<i>Pinus elliottii</i>	5.246	0.9832	0.0508	0.000571	Bonner (1994)
107	<i>Pinus occidentalis</i>	5.047	1.678	0.0206	0.00126	Bonner (1994)
108	<i>Pinus occidentalis</i>	5.101	1.674	0.0354	0.000838	Bonner (1994)
109	<i>Pinus taeda</i>	3.618	-0.2567	0.00064	0.00122	Bonner (1994)
110	<i>Pinus taeda</i>	3.278	-0.73	0.0348	0.000328	Bonner (1994)
111	<i>Pinus taeda</i>	8.838	5.981	0.1034	0.0005476	Fantinatti and Usberti (2007)
112	<i>Pisum sativum</i> *	9.858	5.39	0.0329	0.000478	Ellis et al. (1989)
113	<i>Pongamia pinnata</i>	5.75	3.26	0.04	3e-04	Kundu (2008)
114	<i>Ranunculus sceleratus</i>	6.98	5.01	0.0329	0.000428	Hong et al. (1996)
115	<i>Saccharum</i> spp.	8.805	5.168	5.168	0.000581	Ellis and Hong (2007)
116	<i>Salvia officinalis</i>	5	1.49	0.0329	2e-04	Reza (2014b)
117	<i>Satureja hortensis</i>	4.46	0.391	0.0329	0.000478	Reza (2014b)
118	<i>Secale cereale</i>	6.361	2.059	0.03	0.000201	Reza (2014a)
119	<i>Secale montanum</i>	4.431	0.472	0.03	0.000201	Reza (2014a)
120	<i>Secale montanum</i>	6.114	2.577	0.03856	0.00013	Dehghan and Sharif-Zadeh (2015)
121	<i>Sesamum indicum</i>	7.19	4.02	0.04	0.000428	Ellis et al. (1986)
122	<i>Setaria italica</i>	8.657	4.968	0.0304	0.000504	Ellis and Hong (2007)
123	<i>Setaria italica</i> *	8.678	4.95	0.0329	0.000478	Ellis et al. (1989)
124	<i>Solanum macrocarpon</i>	5.166	3.009	0.094	0.0019	Daniel et al. (2011)
125	<i>Solanum tuberosum</i>	7.923	5.063	0.0325	0.000432	Ellis and Hong (2007)
126	<i>Sorghum bicolor</i>	2.49	-0.3002	0.00725	-0.00057	Ali (2014)
127	<i>Sorghum bicolor</i>	9.472	5.426	0.0324	0.000478	Ellis and Hong (2007)
128	<i>Sorghum bicolor</i>	10.59	6.305	0.041	0.000349	Kuo et al. (1990)
129	<i>Sorghum bicolor</i>	2.49	-0.3002	0.00725	-0.00057	Tabatabaei (2014)
130	<i>Swietenia humilis</i>	5.393	2.391	0.0329	0.000478	Dickie et al. (1990)
131	<i>Tagetes patula</i>	12.22	3.114	0.2769	0.002212	Simões et al. (2008)
132	<i>Terminalia brassii</i>	5.016	2.161	0.0329	0.000478	Tompsett (1986); Tompsett (1992)
133	<i>Thymus daenensis</i>	5	0.753	0.0347	2e-04	Reza (2014b)
134	<i>Thymus transcaspicus</i>	5.065	0.0641	0.03	2e-04	Reza (2014b)
135	<i>Trifolium subterraneum</i>	7.21	3.51	0.04	4e-04	Hong et al. (1996)
136	<i>Triticum aestivum</i>	9.043	5.183	0.0351	0.000475	Ellis and Hong (2007)
137	<i>Triticum aestivum</i> *	9.42	5.859	0.0329	0.000478	Ellis et al. (1990)
138	<i>Ulmus carpinifolia</i>	5.83	3.035	0.0329	0.000478	Tompsett (1986); Tompsett (1992)

Index	Species	K _E	C _W	C _H	C _Q	Reference
139	<i>Vigna radiata</i> *	10.86	6.27	0.0329	0.000478	Ellis et al. (1989)
140	<i>Vigna unguiculata</i>	9.401	5.118	0.0329	0.000478	Ellis et al. (1982); Dickie et al. (1990)
141	<i>Vigna unguiculata</i>	9.102	4.967	0.0295	0.000491	Ellis (1988)
142	<i>Xanthorrhoea preissii</i>	8.77	5.29	0.0382	0.000472	Crawford et al. (2013)
143	<i>Zea mays</i>	10.56	6.366	0.0332	0.000577	Ellis and Hong (2007)
144	<i>Zea mays</i> *	8.579	4.91	0.0329	0.000478	Hong et al. (1996)

* Viability constants are derived from storage experiment at a single temperature. C_H and C_Q here are the universal temperature coefficients (0.0329 and 0.000478 respectively).

Citing viabilitymetrics

Warning in citation("viabilitymetrics"): no date field in DESCRIPTION file
of package 'viabilitymetrics'

Warning in citation("viabilitymetrics"): could not determine year for
'viabilitymetrics' from package DESCRIPTION file

To cite package 'viabilitymetrics' in publications use:

J. Aravind, J. Radhamani, S. Vimala Devi, Sherry Rachel Jacob
and Kalyani Srinivasan (NA). viabilitymetrics: Seed Viability
Calculations and Curve Fitting.
<https://github.com/aravind-j/viabilitymetrics>,
<https://aravind-j.github.io/viabilitymetrics/>.

A BibTeX entry for LaTeX users is

```
@Manual{,
  title = {viabilitymetrics: Seed Viability Calculations and Curve Fitting},
  author = {{J. Aravind} and {J. Radhamani} and {S. Vimala Devi} and {Sherry Rachel Jacob} and {Kalyani Srinivasan (NA)}},
  note = {https://github.com/aravind-j/viabilitymetrics,  
https://aravind-j.github.io/viabilitymetrics/},
  year = {2018},
}
```

Session Info

```
sessionInfo()
```

```
R version 3.4.3 (2017-11-30)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows >= 8 x64 (build 9200)
```

```
Matrix products: default
```

```
locale:
```

```
[1] LC_COLLATE=English_India.1252 LC_CTYPE=English_India.1252
```

```
[3] LC_MONETARY=English_India.1252 LC_NUMERIC=C
[5] LC_TIME=English_India.1252
```

attached base packages:

```
[1] stats      graphics  grDevices  utils      datasets  methods    base
```

other attached packages:

```
[1] viabilitymetrics_0.0.0.9000 ggplot2_2.2.1
```

loaded via a namespace (and not attached):

```
[1] Rcpp_0.12.16      assertthat_0.2.0   rprojroot_1.3-2
[4] digest_0.6.15     utf8_1.1.3         R6_2.2.2
[7] plyr_1.8.4        backports_1.1.2    evaluate_0.10.1
[10] httr_1.3.1        pillar_1.2.1       Rdpack_0.7-0
[13] rlang_0.2.0       rematch_1.0.1      lazyeval_0.2.1
[16] curl_3.1          rstudioapi_0.7     data.table_1.10.4-3
[19] whisker_0.3-2     callr_2.0.2.9002   rmarkdown_1.9.7
[22] pkgdown_0.1.0.9000 desc_1.1.1         labeling_0.3
[25] devtools_1.13.5   stringr_1.3.0      pander_0.6.1
[28] munsell_0.4.3     tinytex_0.4.2      compiler_3.4.3
[31] pkgbuild_0.0.0.9001 htmltools_0.3.6    highlight_0.4.7.2
[34] tibble_1.4.2      roxygen2_6.0.1     crayon_1.3.4
[37] withr_2.1.2       MASS_7.3-49        commonmark_1.4
[40] grid_3.4.3        gtable_0.2.0       magrittr_1.5
[43] scales_0.5.0      bibtex_0.4.2       cli_1.0.0
[46] stringi_1.1.6     debugme_1.1.0      fs_1.2.2
[49] testthat_2.0.0    xml2_1.2.0         tools_3.4.3
[52] purrr_0.2.4       pkgload_1.0.0      yaml_2.1.18
[55] colorspace_1.3-2  gbRd_0.4-11        memoise_1.1.0
[58] knitr_1.20
```

References

- Ali, T. S. (2014). Determination of seed viability constants in sorghum under various storage conditions. *Iranian Journal of Field Crop Science (Iranian Journal of Agricultural Sciences)* 45, 377–387. Available at: <http://www.sid.ir/En/Journal/ViewPaper.aspx?ID=461469>.
- Alivand, ramín, Tavakol Afshari, R., and Sharifzade, farzad (2013). Germination response and estimation of seed deterioration of *Brassica napus* under various storage conditions. *Iranian Journal of Field Crop Science* 44, 69–81. doi:[10.22059/ijfcs.2013.30485](https://doi.org/10.22059/ijfcs.2013.30485).
- Baladi, S., and Balouchi, H. (2016). Evaluation of *Lallemantia royleana* seed longevity under varying conditions of temperature and moisture content. *Seed Science and Technology* 44, 320–326. doi:[10.15258/sst.2016.44.2.03](https://doi.org/10.15258/sst.2016.44.2.03).
- Balouchi, H., Baladi, S., Moradi, A., and Dehnavi, M. M. (2017). The influence of temperature and moisture content on seed longevity of two genotypes of *Linum usitatissimum*. *Seed Science and Technology* 45, 130–138. doi:[10.15258/sst.2017.45.1.08](https://doi.org/10.15258/sst.2017.45.1.08).
- Bam, R. K., Hong, T. D., Ellis, R. H., Kumaga, F. K., and Asiedu, E. A. (2008). Storage behaviour of two contrasting upland rice genotypes. *Ghana Journal of Agricultural Science* 41. doi:[10.4314/gjas.v41i1.46154](https://doi.org/10.4314/gjas.v41i1.46154).
- Belletti, P., Lanteri, S., and Lotito, S. (1991). The influence of temperature and moisture on seed ageing in Iceland poppy (*Papaver nudicaule* L.). *Scientia Horticulturae* 48, 153–158. doi:[10.1016/0304-4238\(91\)90162-r](https://doi.org/10.1016/0304-4238(91)90162-r).
- Bonner, F. (1994). Predicting seed longevity for four forest tree species with orthodox seeds. *Proceedings of the International Seed Testing Association*.

- Chaves, M., and Usberti, R. (2004). Controlled seed deterioration in *Dalbergia nigra* and *Dimorphandra mollis*, endangered Brazilian forest species. *Seed Science and Technology* 32, 813–823. doi:[10.15258/sst.2004.32.3.16](https://doi.org/10.15258/sst.2004.32.3.16).
- Crawford, A. D., Hay, F. R., Plummer, J. A., Probert, R. J., and Steadman, K. J. (2013). One-step fitting of seed viability constants for two Australian plant species, *Eucalyptus erythrocorys* (Myrtaceae) and *Xanthorrhoea preissii* (Xanthorrhoeaceae). *Australian Journal of Botany* 61, 1–10. doi:[10.1071/bt12171](https://doi.org/10.1071/bt12171).
- Daniel, I., Kruse, M., and Börner, A. (2011). Comparative longevity and viability modeling of *Solanum macrocarpon* L. Seeds. *Seed Science and Technology* 39, 680–685. doi:[10.15258/sst.2011.39.3.16](https://doi.org/10.15258/sst.2011.39.3.16).
- Daniel, I., Kruse, M., and Börner, A. (2012). Predicting longevity of *Celosia Argentea* L. Seeds during storage. *Acta Horticulturae* 953, 319–324. doi:[10.17660/ActaHortic.2012.953.44](https://doi.org/10.17660/ActaHortic.2012.953.44).
- Daniel, I., Ng, N., Tayo, T., and Togun, A. (2003). Storage of West African yam (*dioscorea* spp.) seeds: Modelling seed survival under controlled storage environments. *Seed Science and Technology* 31, 139–147. doi:[10.15258/sst.2003.31.1.14](https://doi.org/10.15258/sst.2003.31.1.14).
- Daniel, I. O., Kruse, M., and Börner, A. (2013). Controlled deterioration and predicting viability of okra seed in storage. *International Journal of Vegetable Science* 19, 324–333. doi:[10.1080/19315260.2012.729261](https://doi.org/10.1080/19315260.2012.729261).
- Dehghan, M., and Sharif-Zadeh, F. (2015). Viability model and effect of two drying procedures on seed longevity of *Secale montanum* seeds. *Biomedicine and Nursing* 1, 43–48.
- Demir, I., Kenanoglu, B. B., Mavi, K., Celikkol, T., Hay, F., and Sariyildiz, Z. (2009). Derivation of constants (KE, CW) for the viability equation for pepper seeds and the subsequent test of its applicability. *HortScience* 44, 1679–1682. Available at: <http://hortsci.ashspublications.org/content/44/6/1679>.
- Demir, I., Kenanoglu, B., Hay, F., Mavi, K., and Celikkol, T. (2011). Determination of seed moisture constants (KE, CW) for the viability equation for watermelon, melon, and cucumber seeds. *Seed Science and Technology* 39, 527–532. doi:[10.15258/sst.2011.39.2.23](https://doi.org/10.15258/sst.2011.39.2.23).
- Dickie, J. (1988). Prospects for the long-term storage of apple seeds. *Veröffentlichungen der Landwirtschaftlich-Chemischen Bundesanstalt Linz/Donau* 19, 47–63.
- Dickie, J. B., and Bowyer, J. T. (1985). Estimation of provisional seed viability constants for apple (*Malus domestica borkh.* Cv. Greensleeves). *Annals of Botany* 56, 271–275. doi:[10.1093/oxfordjournals.aob.a087012](https://doi.org/10.1093/oxfordjournals.aob.a087012).
- Dickie, J. B., Ellis, R. H., Kraak, H. L., Ryder, K., and Tompsett, P. B. (1990). Temperature and seed storage longevity. *Annals of Botany* 65, 197–204. doi:[10.1093/oxfordjournals.aob.a087924](https://doi.org/10.1093/oxfordjournals.aob.a087924).
- Dickie, J. B., May, K., Morris, S. V. A., and Titley, S. E. (1991). The effects of desiccation on seed survival in *Acer platanoides* L. And *Acer pseudoplatanus* L. *Seed Science Research* 1. doi:[10.1017/s0960258500000829](https://doi.org/10.1017/s0960258500000829).
- Dickie, J. B., and Smith, R. D. (1995). Observations on the survival of seeds of *agathis* spp. Stored at low moisture contents and temperatures. *Seed Science Research* 5. doi:[10.1017/s09602585000002531](https://doi.org/10.1017/s09602585000002531).
- Ellis, R. (1988). The viability equation, seed viability nomographs, and practical advice on seed storage. *Seed Science and Technology* 16, 29–50.
- Ellis, R. H., and Hong, T. D. (2007). Quantitative response of the longevity of seed of twelve crops to temperature and moisture in hermetic storage. *Seed Science and Technology* 35, 432–444. Available at: <http://centaur.reading.ac.uk/8496/>.
- Ellis, R. H., Hong, T. D., and Roberts, E. H. (1986). Logarithmic relationship between moisture content and longevity in sesame seeds. *Annals of Botany* 57, 499–503. doi:[10.1093/oxfordjournals.aob.a087131](https://doi.org/10.1093/oxfordjournals.aob.a087131).
- Ellis, R. H., Hong, T. D., and Roberts, E. H. (1988). A low-moisture-content limit to logarithmic relations between seed moisture content and longevity. *Annals of Botany* 61, 405–408. doi:[10.1093/oxfordjournals.aob.a087571](https://doi.org/10.1093/oxfordjournals.aob.a087571).
- Ellis, R. H., Hong, T. D., and Roberts, E. H. (1989). A comparison of the low-moisture-content limit to the logarithmic relation between seed moisture and longevity in twelve species. *Annals of Botany* 63, 601–611. doi:[10.1093/oxfordjournals.aob.a087788](https://doi.org/10.1093/oxfordjournals.aob.a087788).

- Ellis, R. H., Hong, T. D., and Roberts, E. H. (1992). The Low-moisture-content Limit to the Negative Logarithmic Relation Between Seed Longevity and Moisture Content in Three Subspecies of Rice. *Annals of Botany* 69, 53–58. doi:[10.1093/oxfordjournals.aob.a088306](https://doi.org/10.1093/oxfordjournals.aob.a088306).
- Ellis, R. H., Hong, T. D., Roberts, E. H., and Tao, K.-L. (1990). Low moisture content limits to relations between seed longevity and moisture. *Annals of Botany* 65, 493–504. doi:[10.1093/oxfordjournals.aob.a087961](https://doi.org/10.1093/oxfordjournals.aob.a087961).
- Ellis, R. H., Osei-Bonsu, K., and Roberts, E. H. (1982). The influence of genotype, temperature and moisture on seed longevity in chickpea, cowpea and soya bean. *Annals of Botany* 50, 69–82. doi:[10.1093/oxfordjournals.aob.a086347](https://doi.org/10.1093/oxfordjournals.aob.a086347).
- Ellis, R. H., and Roberts, E. H. (1980). The influence of temperature and moisture on seed viability period in barley (*Hordeum Distichum* L.). *Annals of Botany* 45, 31–37. doi:[10.1093/oxfordjournals.aob.a085798](https://doi.org/10.1093/oxfordjournals.aob.a085798).
- Ellis, R., and Roberts, E. (1981). The quantification of ageing and survival in orthodox seeds. *Seed Science and Technology*.
- Fantinatti, J. B., and Usberti, R. (2007). Seed viability constants for *Eucalyptus grandis*. *Pesquisa Agropecuária Brasileira* 42, 111–117. doi:[10.1590/s0100-204s2007000100015](https://doi.org/10.1590/s0100-204s2007000100015).
- Far, F. G., Soltani, A., and Sadeghipour (2010). Determination of seed viability constants in medicinal pumpkin (cucurbita pepo l. Subsp. Pepo. Convar. Pepo var. Styriaca greb), borago (*Borago officinalis* L.) And black cumin (*Nigella sativa* L.). *Journal of Plant Production (Journal of Agricultural Sciences and Natural Resources)* 17, 53–66. Available at: <http://www.sid.ir/En/Journal/ViewPaper.aspx?ID=214959>.
- Hay, F. R., Mead, A., Manger, K., and Wilson, F. J. (2003). One-step analysis of seed storage data and the longevity of *Arabidopsis thaliana* seeds. *Journal of Experimental Botany* 54, 993–1011. doi:[10.1093/jxb/erg103](https://doi.org/10.1093/jxb/erg103).
- Hong, T. D., Linington, S., and Ellis, R. H. (1996). *Seed Storage Behaviour: A Compendium*. Rome, Italy: International Plant Genetic Resources Institute (IPGRI).
- Ignácio, V. L. (2013). Germinação e conservação de sementes de Balfourodendron riedelianum (Engler) Engler. Available at: <http://tede.unioeste.br:8080/tede/handle/tede/1454>.
- Kebreab, and Murdoch (1999). Effect of temperature and humidity on the longevity of *orobanche* seeds. *Weed Research* 39, 199–211. doi:[10.1046/j.1365-3180.1999.00138.x](https://doi.org/10.1046/j.1365-3180.1999.00138.x).
- Kraak, H. L., and Vos, J. (1987). Seed viability constants for lettuce. *Annals of Botany* 59, 343–349. doi:[10.1093/oxfordjournals.aob.a087323](https://doi.org/10.1093/oxfordjournals.aob.a087323).
- Kruse, M., Ghiasi, K. G., and Schmohl, S. (2005). The seed viability equation for analysing seed storage behaviour. Available at: <https://www.seedtest.org/upload/cms/user/presentation5Kruseetal.pdf>.
- Kundu, M. (2008). Prediction of viability of seeds of *Pongamia pinnata* (Karanj) under controlled conditions. *Seed Science and Technology* 36, 481–485. doi:[10.15258/sst.2008.36.2.23](https://doi.org/10.15258/sst.2008.36.2.23).
- Kuo, W. H. J. (1991). On the prediction of the storage longevity of muskmelon seeds. *Memoirs of the College of Agriculture* 31, 22–29.
- Kuo, W. H. J., Shan, M. L., and Tseng, M. T. (1990). Effects of temperature and seed moisture-content on the longevity of sorghum seeds. *Journal of the Agricultural Association of China*, 32–41.
- Lee, M. H., Hong, S. H., Na, C. S., Kim, J. G., Kim, T. W., and Lee, Y. H. (2017). Analysis of seed storage data and longevity for *Agastache rugosa*. *Korean Journal of Environmental Biology* 35, 207–214.
- Muthoka, P., Hay, F., Dida, M., Nyabundi, J., and Probert, R. (2009). Moisture content and the longevity of seeds of six *euphorbia* species in open storage. *Seed Science and Technology* 37, 383–397. doi:[10.15258/sst.2009.37.2.12](https://doi.org/10.15258/sst.2009.37.2.12).
- Pozitano, M., and Usberti, R. (2009). Seed controlled deterioration of three interspecific elephant grass pearl millet hybrids. *Revista Brasileira de Zootecnia* 38, 428–434. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-35982009000300005&nrm=iso.

- Reza, E. H. (2014a). Estimation of seed viability constants for tall wheatgrass, cocksfoot, rye, and sheep fescue to inform gene banking decisions. *Iranian Journal of Plant Physiology* 4, 1145–1149. Available at: <http://www.sid.ir/En/Journal/ViewPaper.aspx?ID=518161>.
- Reza, E. H. (2014b). Prediction of seed regeneration time of some medicinal plants by estimation of viability equation constants. *Iranian Journal of Field Crop Science* 45, 399–407. doi:[10.22059/ijfcs.2014.53536](https://doi.org/10.22059/ijfcs.2014.53536).
- Simões, F., Usberti, R., and Paiva, P. (2008). Controlled seed deterioration in *Tagetes patula* L. Cultivars. *Seed Science and Technology* 36, 524–533. doi:[10.15258/sst.2008.36.3.02](https://doi.org/10.15258/sst.2008.36.3.02).
- Sinício, R., Lopes, J., Silva, D., and Mattedi, A. (2009). Longevity equation for tomato seeds. *Seed Science and Technology* 37, 667–675. doi:[10.15258/sst.2009.37.3.14](https://doi.org/10.15258/sst.2009.37.3.14).
- Tabatabaei, S. A. (2014). Determination of seed viability constants in sorghum under various storage conditions. *Iranian Journal of Field Crop Science* 45, 377–387. doi:[10.22059/ijfcs.2014.53534](https://doi.org/10.22059/ijfcs.2014.53534).
- Tompsett, P. B. (1984). The effect of moisture content and temperature on the storage life of *Araucaria columnaris*. *Seed Science and Technology* 12, 801–816.
- Tompsett, P. B. (1986). The effect of temperature and moisture content on the longevity of seed of *Ulmus carpinifolia* and *Terminalia brassii*. *Annals of Botany* 57, 875–883. doi:[10.1093/oxfordjournals.aob.a087172](https://doi.org/10.1093/oxfordjournals.aob.a087172).
- Tompsett, P. B. (1992). A review of the literature on storage of dipterocarp seeds. *Seed Science and Technology* 20, 251–267.
- Usberti, R. (2007). Performance of tropical forage grass (*Brachiaria brizantha*) dormant seeds under controlled storage. *Seed Science and Technology* 35, 402–413. doi:[10.15258/sst.2007.35.2.15](https://doi.org/10.15258/sst.2007.35.2.15).
- Usberti, R., and Gomes, R. B. R. (1998). Seed viability constants for groundnut. *Annals of Botany* 82, 691–694. doi:[10.1006/anbo.1998.0736](https://doi.org/10.1006/anbo.1998.0736).
- Usberti, R., Roberts, E. H., and Ellis, R. H. (2006). Prediction of cottonseed longevity. *Pesquisa Agropecuária Brasileira* 41, 1435–1441. doi:[10.1590/s0100-204X2006000900013](https://doi.org/10.1590/s0100-204X2006000900013).
- Wilson, D. O., and McDonald, M. B. (1989). A probit planes method for analyzing seed deterioration data. *Crop Science* 29, 471–476. doi:[10.2135/cropsci1989.0011183X002900020046x](https://doi.org/10.2135/cropsci1989.0011183X002900020046x).
- Zewdie, M., and Ellis, R. (1991). Response of tef and niger seed longevity to storage temperature and moisture. *Seed Science and Technology* 19, 319–329.