The seed viability equation for analysing seed storage behaviour

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Seed survival curves of three maize seed lots stored at 40°C and 10% moisture content

E. H. Roberts

Ellis and Roberts, 1981
Theoretical seed survival according to the normal distribution

from Ellis and Roberts, 1961
Probit - transformation

Probit value 0.9

germination 82%
Transformation of a seed survival curve from the percent scale to a line on the probit scale.

\[
\sigma = 10^{\frac{K_E - C_W \log(SFG) - C_H T - C_Q T^2}{\sigma}}
\]
Probit Analysis
Linear Regression by taking into account the varying precision of the data points as produced by the transformation

Weighing coefficient:

\[ W = \frac{z^2}{p \cdot q} \]

The weighing coefficients depend on the estimates, not on the observations.
The improved seed viability equation

\[ \nu = K_i - \frac{1}{10^{K_E - C_W \log (SFG) - C_H T - C_Q T^2}} p \]

with: \( \nu \) = germination (probit) after storage for \( p \) days
\( K_i \) = initial germination in probit
\( SFG \) = seed moisture content in %
\( T \) = temperature in °C
\( p \) = storage period in days
\( K_E, C_W, C_H \) und \( C_Q \) = species specific constants
## Procedure for determination of viability constants

<table>
<thead>
<tr>
<th>mc</th>
<th>30°C</th>
<th>35°C</th>
<th>40°C</th>
<th>45°C</th>
<th>50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>12%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.532</td>
<td>-1.387</td>
<td>-2.432</td>
<td>-3.063</td>
<td></td>
</tr>
<tr>
<td>13%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.535</td>
<td>-0.884</td>
<td>-1.852</td>
<td>-2.532</td>
<td>-3.720</td>
</tr>
<tr>
<td>14%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1.003</td>
<td>-1.337</td>
<td>-2.431</td>
<td>-3.132</td>
<td></td>
</tr>
<tr>
<td>15%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1.844</td>
<td>-2.299</td>
<td>-2.711</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Multiple, nonlinear regression: \[
\frac{1}{\text{slope}} = 10^{K_E - C_W \log(mc) - C_H T - C_Q T^2}
\]
Non-linear regression for the seed viability equation by using SAS

proc nlin data= ....  noprint outest=estm;
parameters Ke =6 to 10 by .2
       Cw = 3 to 6 by .1
       Ch = .03 to .06 by .001
       Cq = .0002 to .0005 by .00001;
model prkf = Ki-(days*(10**(-Ke + Cw*log10(MC) + Ch*T+Cq*T**2)));
der.ke = +days*(10**(-Ke+Cw*log10(MC)+Ch*T+Cq*T**2))*log(10);
der.cw = -days*(10**(-Ke+Cw*log10(MC)+Ch*T+Cq*T**2))*log(10)*log10(MC);
der.ch = -days*(10**(-Ke+Cw*log10(MC)+Ch*T+Cq*T**2))*log(10)*T;
der.cq = -days*(10**(-Ke+Cw*log10(MC)+Ch*T+Cq*T**2))*log(10)*T**2;
output out=pred p=tp r=tr;
run;
## Constants for the improved seed viability equation for selected agricultural and vegetable crops

<table>
<thead>
<tr>
<th>Species</th>
<th>$K_E$</th>
<th>$C_W$</th>
<th>$C_H$</th>
<th>$C_Q$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>9,983</td>
<td>5,896</td>
<td>0,04</td>
<td>0,000428</td>
</tr>
<tr>
<td>Wheat</td>
<td>10,1</td>
<td>5,730</td>
<td>0,0563</td>
<td>-</td>
</tr>
<tr>
<td>Maize</td>
<td>8,579</td>
<td>4,910</td>
<td>0,0329</td>
<td>0,000428</td>
</tr>
<tr>
<td>Pea</td>
<td>9,860</td>
<td>5,390</td>
<td>0,0329</td>
<td>0,000478</td>
</tr>
<tr>
<td>Garden bean</td>
<td>9,08</td>
<td>5,20</td>
<td>0,0057</td>
<td>0,00079</td>
</tr>
<tr>
<td>Rape seed</td>
<td>7,718</td>
<td>4,54</td>
<td>0,0329</td>
<td>0,000478</td>
</tr>
<tr>
<td>Soybean</td>
<td>7,748</td>
<td>3,979</td>
<td>0,053</td>
<td>0,000228</td>
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<tr>
<td>Sunflower</td>
<td>6,74</td>
<td>4,160</td>
<td>0,0329</td>
<td>0,000478</td>
</tr>
<tr>
<td>Linseed</td>
<td>7,76</td>
<td>4,860</td>
<td>0,0329</td>
<td>0,000478</td>
</tr>
<tr>
<td>Sugarbeet</td>
<td>8,943</td>
<td>4,723</td>
<td>0,0329</td>
<td>0,000478</td>
</tr>
<tr>
<td>Onion</td>
<td>6,975</td>
<td>3,470</td>
<td>0,04</td>
<td>0,000428</td>
</tr>
<tr>
<td>Salad</td>
<td>8,218</td>
<td>4,797</td>
<td>0,0489</td>
<td>0,000365</td>
</tr>
<tr>
<td>Tomato</td>
<td>6,5017</td>
<td>3,1807</td>
<td>0,0324</td>
<td>0,000431</td>
</tr>
</tbody>
</table>
Applications of the seed viability equation: calculated seed survival curves for lettuce

![Graph showing germination percentage over storage period for different seed viability equations. The graph includes lines for 10.0%, 14.0%, 15.0%, and 16.0% viability, plotted against weeks of storage.](image-url)
Applications of the seed viability equation: Iso – germination curves

Conditions:
initial germination 98%,
after one year of storage still 90% germination
Ultra-dry seed storage
The Vienna Oat Sample of 1877

Initial germination 96%, after 110 years of storage still 90% germination

presumable storage conditions
Project: Improving the seed viability equation by including seed oil content as a factor.

Example indicating the need: Seed survival probit lines of three seed lots of sunflower varieties differing in seed oil content.