Comparison of Measurement Methods Using the Sensitivity Ratio: An Application to Screening for Disease Resistance in Soybeans

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Introduction
Whenever there are two or more methods for the measurement of the same property, there arises a problem of determining the best method in terms of technical merits. From a statistical point of view, evaluation of the technical merits should be based on a comparison of their precisions. There are several measures of precision which can be used, such as the standard deviation, the coefficient of variation, confidence intervals, the range and the sensitivity ratio. Of all the measures of precision, the sensitivity ratio is the only one that is invariant with respect to the scales in which the measurements are expressed.

Objectives
1) Explain the concept of Sensitivity Ratio (SR)
2) Apply SR to evaluate two popular resistance screening methods of soybean lines to white mold.
   a) Compare two methods with different measurement scales
   b) Compare two methods with the same scale

Materials and Methods
To describe the sensitivity ratio, suppose two methods M and N are used to measure some property Q.
Assume M is a function of Q, and so M=f (Q)  
\[ \hat{Q} = f^{-1}(M) \] then the variance of Q  
\[ \sigma^2_Q = \frac{d f^{-1}}{dM} \cdot \sigma^2_M \] by the delta rule

1/ \[ \sigma^2_Q = \frac{d f}{dQ} \cdot \sigma^2_M \] (sensitivity of M)

Similarly for measurement method, N, assuming N= h (Q) then
1/ \[ \sigma^2_N = \frac{d h}{dQ} \cdot \sigma^2_N \] (sensitivity of N)

Dividing the 2 sensitivities gives the sensitivity ratio
\[ \text{SR}(M/N) = \frac{dM}{dN} \cdot \frac{\sigma^2_M}{\sigma^2_N} \]

If SR(M/N) > 1, then M is better

SR only depends on the relationship between M and N and \( \sigma^2_M \) and \( \sigma^2_N \)
SR is scale-independent
SR can be easily obtained from experimental data
Can test if SR ≤ 1 using an F-test

Comparison of Measurement Methods using the Sensitivity Ratio
Comparison of two Resistance Screening Methods with Different Disease Measurement Scales

Detached Leaf Test (DLT)
In the lab, the four trifoliates from the same block were labeled and placed in a pan, as in incomplete blocks, then inoculated with isolates.

Cut Stem Method (CSM)
Main stems of the 5-week old plants were cut horizontally with a sterile razor blade 0.5cm above the fourth node. A plug was immediately placed on the stem, then the inoculated plants were incubated in a mist chamber with humidity maintained over 80%.

Results
Comparison of Two Disease Measurement Methods With the Same Scale
Digital measurements of the lesion area are determined by Scion computer software from a digital photograph.

Hand measurements are taken using a metric ruler. Lesion area= diameter (length) X diameter (width) X 3.14

Comparison of two Resistance Screening Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>RMSE</th>
<th>CV</th>
<th>Corr</th>
<th>Slope</th>
<th>SR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLT</td>
<td>1.7924</td>
<td>24%</td>
<td>0.6910</td>
<td>0.2303</td>
<td>0.3183</td>
</tr>
<tr>
<td>CSM</td>
<td>2.4768</td>
<td>17%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RMSE: DLT is better
CV: CSM is better
SR(DLT/CSM): CSM is much better

Application of the Sensitivity Ratio to Resistance Screening in Soybeans
Compare two measurement methods, DLT and CSM.

Experimental set up
The three cultivars were Williams82, Bell and NKS19-90.
Two isolates, 143 and 279 of Sclerotinia sclerotiorum (white mold).
The experiment was conducted as an incomplete block design with 15 blocks of size 4 and 10 replications.
Used slope of regression of DLT on CSM as estimate of dM/dN.
Use RMSE’s as estimates of \( \sigma^2_M \) and \( \sigma^2_N \).

Results

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Hand</td>
<td>1.3733</td>
<td>34%</td>
<td>0.6339</td>
<td>0.4550</td>
<td>0.6850</td>
</tr>
<tr>
<td>Digital</td>
<td>1.0244</td>
<td>35%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

RMSE: Digital is better
CV: Hand is better
SR(H/D): Digital is better

Conclusion
SR gives a different conclusion than the RMSE and CV.
SR is better since it is scale-independent.
SR can also be used when methods of measurement have the same scale.