Fitopatometría

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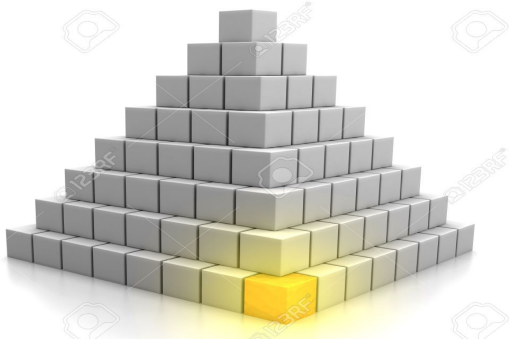
"Our ability to understand a phenomenon is proportional to our ability to measure it"
Lord Kelvin (1824-1907)

"How can plant pathologists apply advanced statistical procedures or develop quantitative models based upon disease assessment data of unknown accuracy and precision?"
David Mackenzie, 1979

"Without quantification of disease, no studies in epidemiology, no assessment of crop losses, and no plant disease surveys and their applications would be possible"
Kranz, 1988

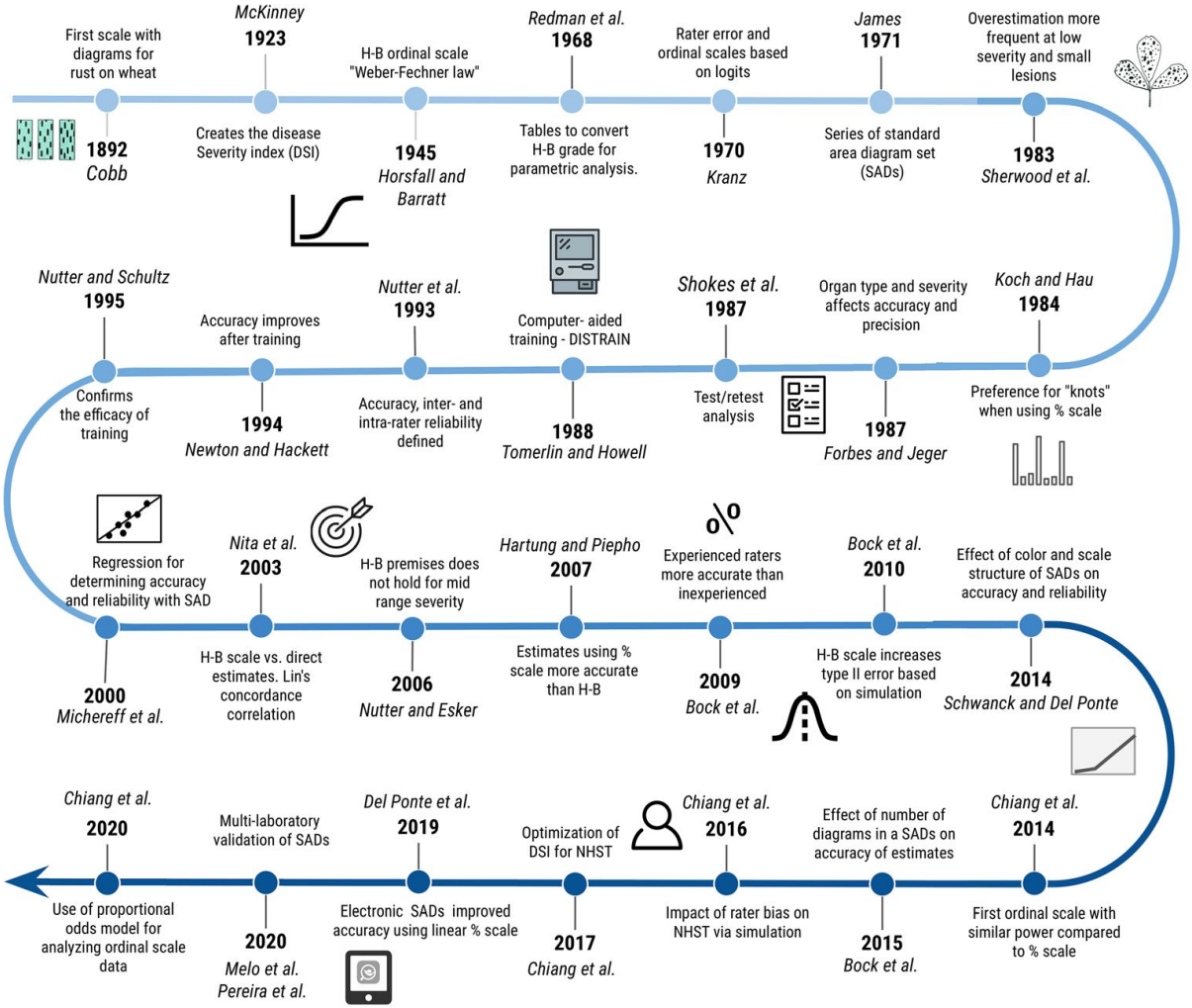
"The cornerstone of epidemic analysis"
Campbell and Neher, 1994



Phytopathometry

Branch of plant pathology (phytopathology) that is concerned with estimation or measurement of the amount of plant disease expressed by symptoms of disease or signs of a pathogen on a single or group of specimens.

Phytopathometry is critical for many reasons, including analyzing yield loss due to disease, breeding for disease resistance, evaluating and comparing disease control methods, understanding coevolution, and studying disease epidemiology and pathogen ecology.
Bock et al., 2021



Bock et. al, 2021

Disease intensity

General term for the amount of disease present in a population.

Disease incidence
Proportion of plants (leaves, etc.) diseased. Most useful when mean severity is low to moderate

+ fast, and easier to train scouts
+ maybe more objective

Disease severity
Relative or absolute area/volume of plant tissue affected by disease. Often represented as a proportion (0 to 1) or percentage (0 to 100). “Degree of infection”

+ more informative

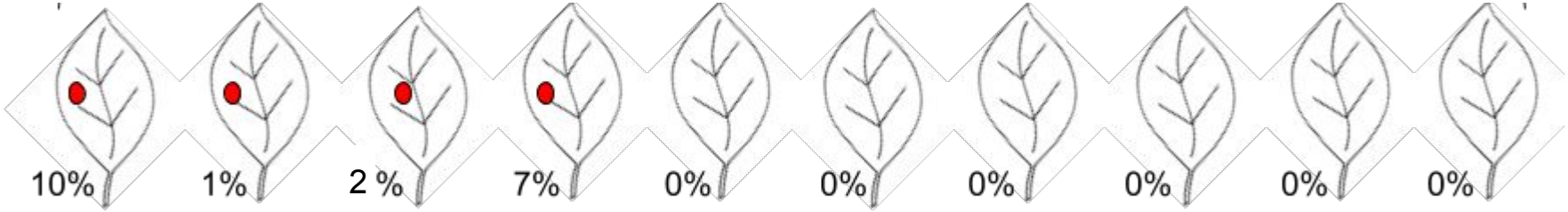
Disease count
Number of lesions (or other units of infection) per plant or per area of plant tissue. A type of density. Often considered to be a form of severity. Most useful when lesions are not too small, when counts are small, and sizes are similar

Non visual methods: canopy reflectance or molecular or immunological methods

Nutter et. al, 1991

Scale-level

	Severity	Incidence	Prevalence
Region			x
Field	Conditional Sev Mean Sev	x	
Individual	x	x	
Tissue	x		

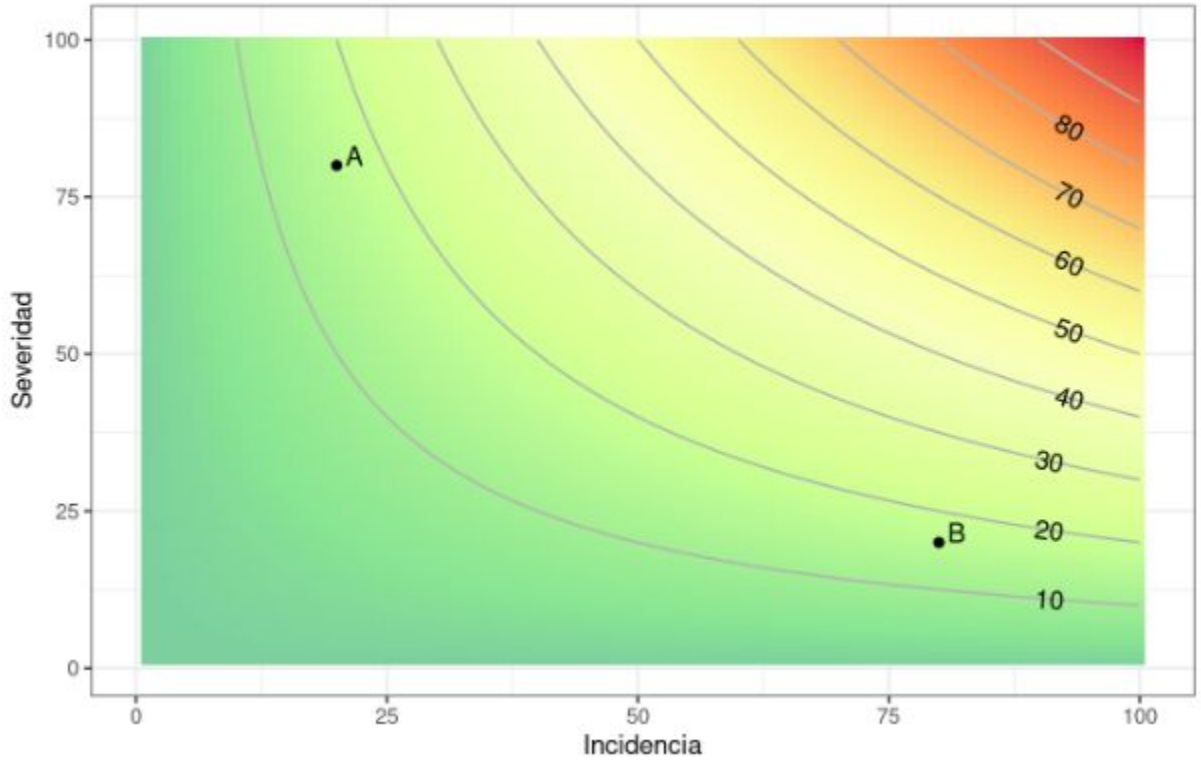


Disease incidence and severity, n =10

20/4 = 5% conditional severity
20/10 = 2% mean severity

4/10 = 0,4 incidence (*100 = 40%)

5% cond sev * 0,4 inc = 2% mean sev


100
75
50
25
0
Severidad
0
25
50
75
100
Incidencia
A
B
80
70
60
50
40
30
20
10

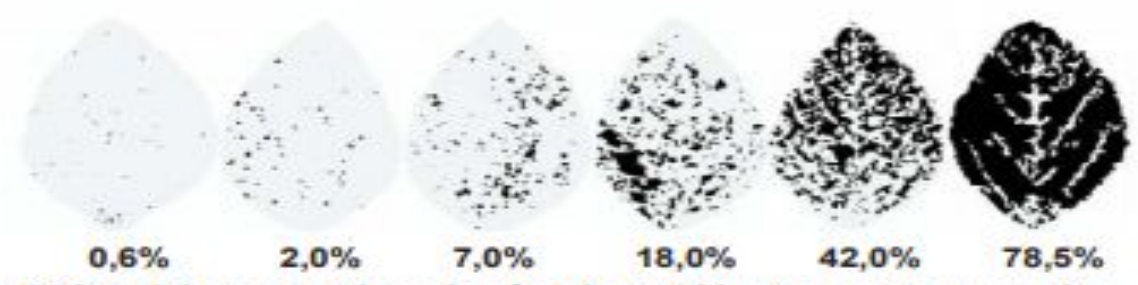
Estimating disease severity

1. Direct estimation (assign each specimen a severity value)
    a. without aid
    b. with aid of disease diagrams
2. Using ordinal disease scales:
    a. Quantitative intervals
    b. Qualitatives classes

1. Disease severity with aid of SAD

Standard area diagrams (SADs) are defined as a set of illustrations depicting incremental percent severity values (Nutter et al. 1993) -> **Escala diagramática**

The SADs are designed to aid raters to accurately interpolate the percent severity between the guide reference pair most closely resembling the specimen in question (James et al. 1971).



Diagrammatic scale of soybean (glycine max) rust severity (percentage of diseased leaf area) . Godoy et al 2006

Del Ponte et. al, 2017

2A. Ordinal disease rating scales - quantitative

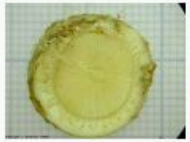
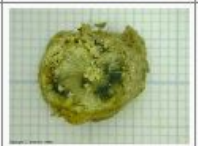
The disease severity index (DSI), is a single index number for summarising a large amount of information on disease severity (Chester, 1950; Chaube & Singh, 1991).

When used, DSIs are often based on a special type of **ordinal scale data**. Here, we define a 'quantitative' ordinal scale as one that comprises a number of **categories** of known, specified **ranges of numeric values**, as described by Hartung & Piepho (2007)

The author's guide for the American Phytopathological Society (APS, 2017) publications states that 'if ordinal rating scores are used for ranges of disease severity, each score should be converted to the midpoint of the corresponding disease severity range prior to use of a parametric analytical technique'

Chiang et al., 2017

QuantiPest - PHOMADIDACTE

Severity class	Description	Example 1 (click on the picture to magnify it)	Example 2 (click on the picture to magnify it)
1	Healthy plant, no visible lesions.		
2	0-25% of discoloured cross-section.		
3	25-50% of discoloured cross-section.		
4	50-75% of discoloured cross-section.		
5	75-100% of discoloured cross-section.		
6	Section without any living tissue.		

notes in Table 1. Plants in each plot were rated for disease severity index (DSI) and disease incidence (13) by means of a "quarter scale" (8). Plants were rated from 0 to 4, where 0 = no symptoms, 1 = 1 to 25% of the plant with symptoms, 2 = 26 to 50% of the plant with symptoms, 3 = 51 to 75% of the plant with symptoms, and 4 = 76 to 100% of the plant with symptoms. DSI was calculated for each plot on a percentage basis by the following formula:

$$\text{DSI}(\%) = \frac{\sum(\text{scores of all plants})}{4 \times (\text{total number of plants})} \times 100$$

Vieira et. al, 2010

When the calculated DSI in Eqn 2 equals 1.0, the corresponding DSI estimate (%) in Eqn 1 is 25% (=1/4). However, in this case, a DSI of 1.0 represents severities of 1–25% based on the grading method. Thus, using the midpoint of 1–25% (13%) rather than 25% should be more sensible based on previous observations

When the calculated DSI in Eqn 2 is 2.0, the corresponding DSI estimate (%) in Eqn 1 is 50% (=2/4). A more sensible DSI on a percentage basis should be the midpoint value of 25–50%, which is 37.5%.

when the calculated DSI is 1.5 in Eqn 2, the calculated DSI estimate (%) is 37.5% (the midpoint of 25–50%) if using the interpolation method in Eqn 1, but in fact the DSI on a percentage basis should be the mid-point value of 13.0% (the midpoint of the 1–25% interval) and 37.5% (the midpoint of the 25–50% interval), which is 25.25%.

sheet_example

The work to perform a midpoint conversion to ensure compatibility with parametric analysis is reasonable (Bock et al., 2010b).

We made this choice because the mid-point value is an ‘approximation’ to prevent excessive bias or loss of precision. Although the mid-point is not ideal, it is preferable in plant pathology and plant breeding when a scale must be used.

For example, Madden et al. (2007) characterised that ‘one should **convert each class value to a severity on a percentage scale**. The common approach is to use the **mid-point of the severity range for each class**’.

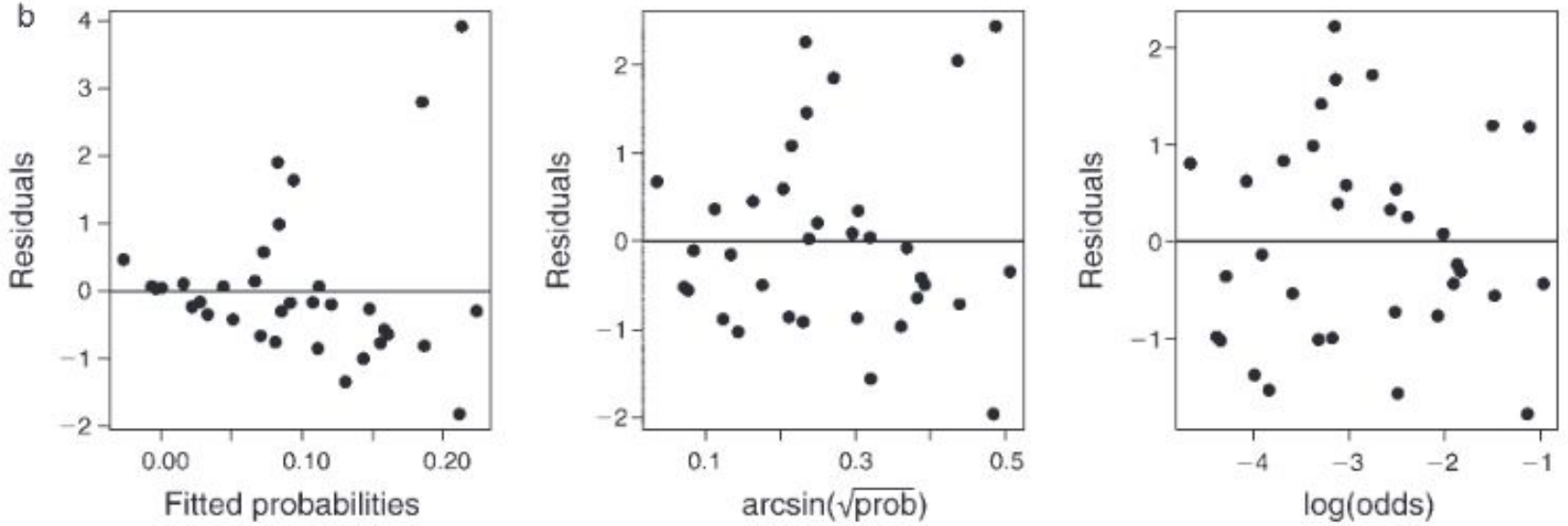
Although ordinal scales may be analyzed non-parametrically for some purposes, the power of the non-parametric test is not as high as that of the corresponding parametric test (Bock et al., 2010b).

Disease severity transformations prior to analysis

Because the values of the DSI are from 0% to 100%, **arcsine square root** or the **logit (log odds)** transformation are commonly suggested to ensure:

(a) additivity of effects, (b) constant variance across treatments and (c) a normal distribution or residuals.

(Only the logit transformation satisfies all three of the criteria)



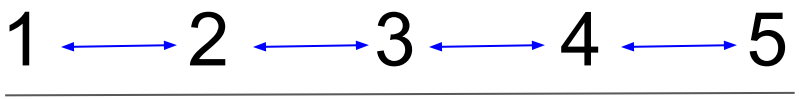
2B. Ordinal disease rating scales - qualitative

• Ordered categories of severity
• As with disease scales (and diagrams), one observes a specimen and assigns it a category (class) value (a score)

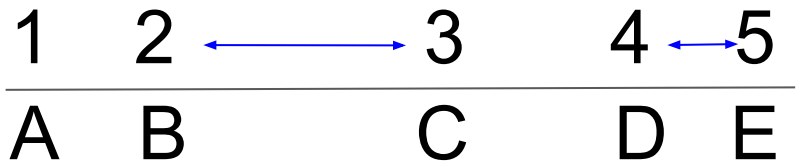
Systemic diseases, caused by viruses and many root diseases.

The specific rating used does not have any measurable physical interpretation (Madden et al., 2007).
non-parametric analysis (Shah & Madden, 2004)
ordinal logistic regression (McCullagh and Nelder, 1989)

2B. Ordinal disease rating scales - qualitative



By using ANOVA, one is assuming that the rating scores represent equal gradations on an underlying true disease severity scale

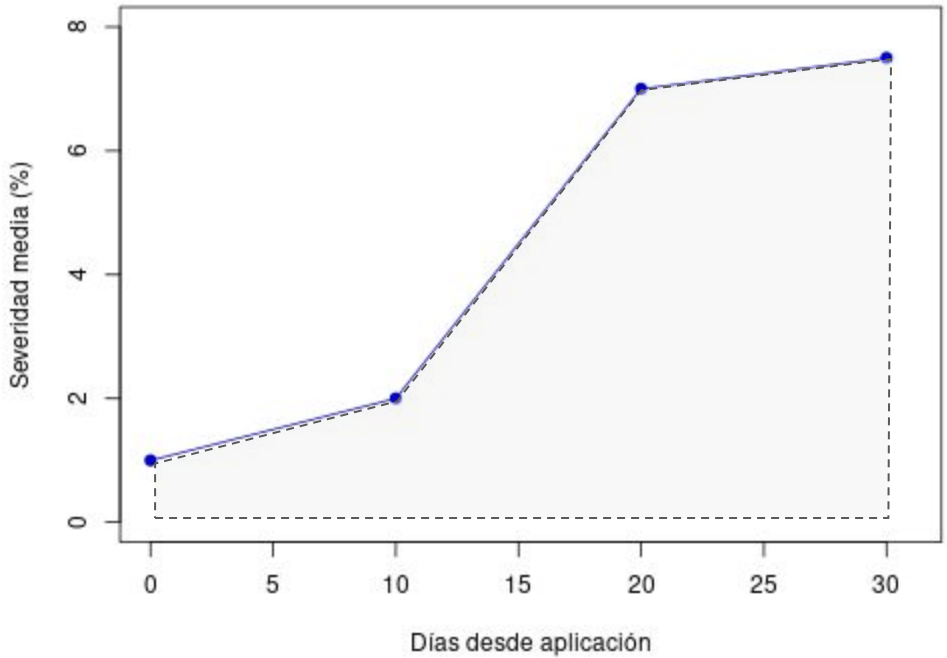


Scores are only indicators of the order of the specimens, not the differences in the specimens (in terms of severity)

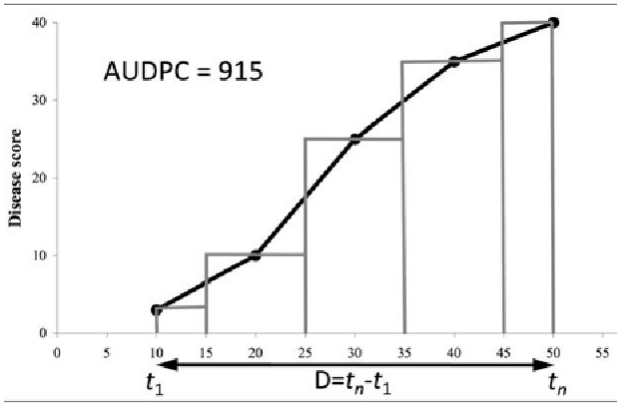
1 = Healthy plants
2 = Isolated plants with very few symptoms in the lower canopy
3 = Most or all plants with one or more leaves affected in the lower canopy
4 = Most or all plants with many leaves affected on plant, few leaves affected in the mid canopy
5 = Severe defoliation in mid and upper canopy

Madden, 2007

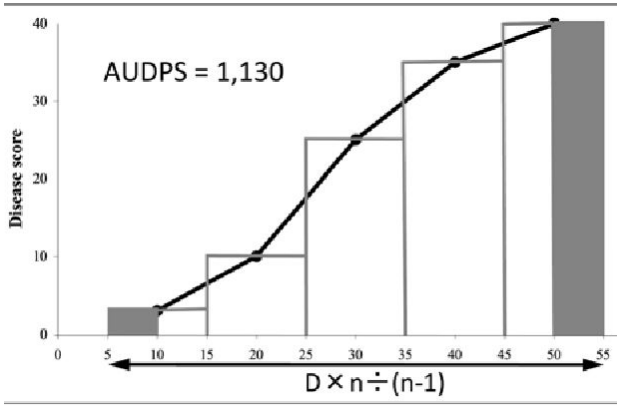
Integrating time to disease assessments



Area under the disease progress curve (AUDPC)

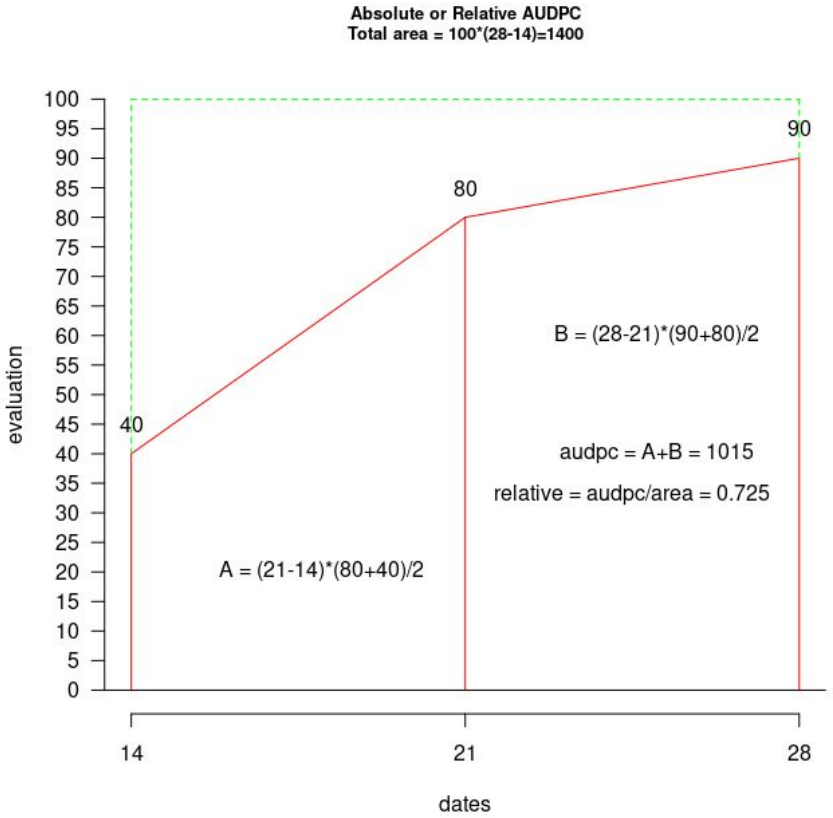


Area under the disease progress stairs (AUDPS)

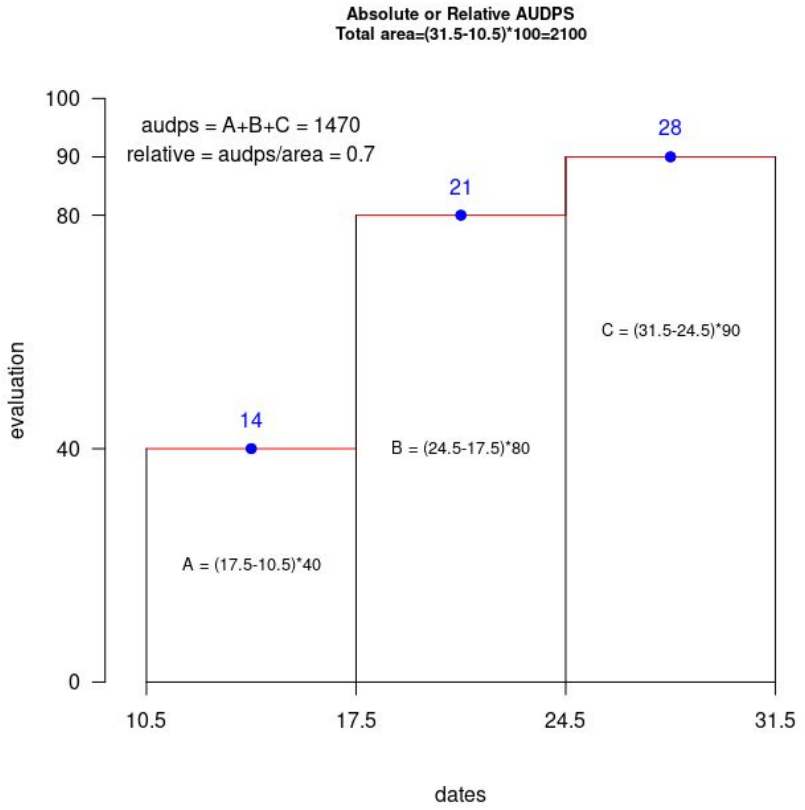


Simko, I., & Piepho, H. P. (2012). The area under the disease progress stairs: calculation, advantage, and application. Phytopathology, 102(4), 381-389.

Area under the disease progress curve (AUDPC)



Area under the disease progress stairs (AUDPS)



Metrics[a]	Area	Covered timespan	Value for an individual if four evaluations were performed at every time unit with scores of, for example, 1, 2, 3, and 10[b]
AUDPC	Absolute area across all evaluations	Difference in time between last (t_n) and first (t_1) evaluation $t_n - t_1$	Sum of scores (y) from all evaluations minus half of scores from first (y_1) and last (y_n) evaluation $(\sum_{t1}^{tn} y) - \frac{y1 + yn}{2}$ Example: AUDPC = 10.5
AUDPS	Absolute area across all evaluations	Difference in time between last (t_n) and first (t_1) evaluation multiplied by extrapolated missing weight calculated from the number of evaluations (n) $(t_n - t_1) \times \left(\frac{n}{n-1}\right)$	Sum of scores (y) from all evaluations $\sum_{t1}^{tn} y$ Example: AUDPS = 16
sAUDPC	Standardized area for a single time unit	A single time unit from AUDPC	$\frac{AUDPC}{tn - t1}$ Example: sAUDPC = 3.5
sAUDPS	Standardized area for a single time unit	A single time unit from AUDPS	Mean ($\bar{y}$) of scores from all evaluations $\frac{AUDPS \times (n-1)}{(tn - t1) \times n} = \bar{y}$ Example: sAUDPS = 4.0
rAUDPC	Relative area to maximum potential AUDPC area	Not applicable, value is a proportion or percentage (if multiplied by 100)	$\frac{AUDPC}{AUDPC\ max}$ If maximum disease score for the example is 10, $AUDPC_{max}$ = 30 and rAUDPC = 0.35
rAUDPS	Relative area to maximum potential AUDPS area	Not applicable, value is a proportion or percentage (if multiplied by 100)	$\frac{AUDPS}{AUDPS\ max}$ If maximum disease score for the example is 10, $AUDPS_{max}$ = 40 and rAUDPS = 0.4

[a] AUDPC = area under the disease progress curve and AUDPS = area under the disease progress stairs. Though absolute, standardized (s), and relative (r) values calculated by a method differ, the coefficient of determination between values obtained by the same method (e.g., AUDPS, sAUDPS, and rAUDPS) from the same dataset always equals 1 ($R^2 = 1$).

[b] An example with four evaluations performed at every time unit is provided to demonstrate the difference in results calculated by the two methods (AUDPC versus AUDPS). In this simple example, the scores recorded for four successive evaluations were 1, 2, 3, and 10, with the maximum potential score of 10. Note that formulas (and related explanations) for calculating AUDPC and AUDPS apply only for evaluations performed at every time unit. If evaluations were not performed at every time unit, formulas for AUDPC and AUDPS are more complex; for detailed explanation, see Simko and Piepho (2012).

Assessment of plant diseases and losses

The total leaf area affected by disease, i.e., pustules or lesions, including any accompanying chlorosis, necrosis, or defoliation (I), is likely to be better correlated with losses in yield than with pustule or lesion area alone (40). Samborski & Peturson demonstrated the significance of recording chlorosis or necrosis when they reported substantial losses in yield of wheat cultivars hypersensitive to leaf rust.

The simplest disease-assessment method is usually the one least prone to error; an example of such a method is the assessment of disease on individual cereal leaves. Each disease present is assessed individually, and because the observer is assessing one disease on one leaf at a time, the error attached to any particular assessment is smaller than when many leaves have to be assessed
at the same time, as for example in the Large & Doling cereal-mildew key

James, W. C. (1974). Assessment of plant diseases and losses. Annual review of Phytopathology, 12(1), 27-48.

Assessment of plant diseases and losses

If pathologists want to relate their disease progress curves to growth, it would be logical to subtract the area of diseased leaves from the LAD by integrating the size [(1 - x) L] of the healthy and operating factory during the season.

This calculation from the progress of x and L gives what we call healthy leaf area duration or HAD (days).

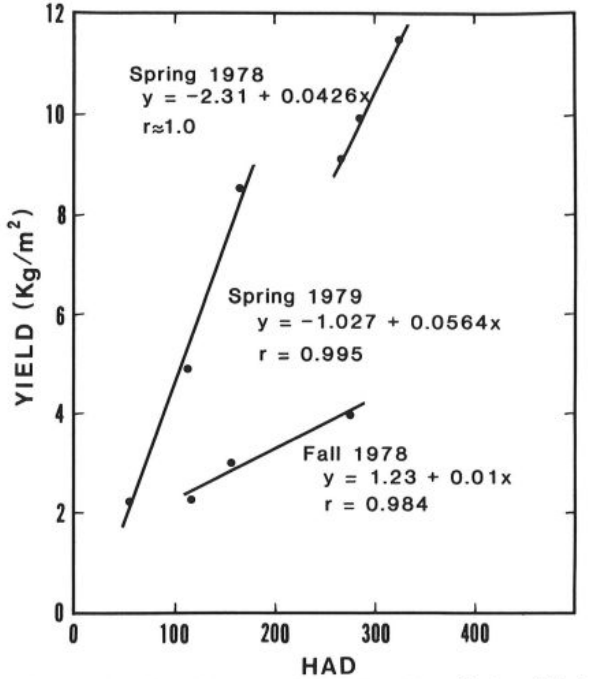


Fig. 4. The healthy leaf area duration HAD and kg m^{-2} tuber yield of potatoes grown by Rotem et al (16,17) in three seasons.

Waggoner, P. E., & Berger, R. D. (1987). Defoliation, disease, and growth. *Phytopathology*, *77*(3), 393-398.

Conceptos - datasets

- Incidencia
- Prevalencia
- Severidad: condicional / media

Olivo/xylella; cebada

- Índice de enfermedad — poroto/sclerotinia; mani/carbón
- AUDPC/ AUDPS — Canola/phoma
- Enfermedades que inducen senescencia: DAF — Trigo/Manchas