PLP 6404
Epidemiology of Plant Diseases
Spring 2015

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Lecture 2: Measurement of disease: incidence, severity, diagrams and scales

The measurement of disease intensity is one of the most important and often most difficult tasks in plant disease epidemiology.

Quantification of disease is essential for:

- crop loss assessment
- pathogen population dynamics
- timing management
- evaluating host resistant/pathogen virulence
- evaluating control strategies

The degree of certainty in conclusions and the ability to differentiate true effects can never be better or more reliable than the reliability of the disease intensity values!

Disease measurements:

- **Intensity:** the amount of disease (overall estimate)
- **Incidence:** proportion of plants or plant parts diseased, obtained by counting
- **Severity:** proportion of area or length diseased, a continuous variable obtained by measuring
- **Others** such as lesion density (number of lesions per unit leaf area)

Types of data for intensity measurement:

- nominal – qualitative, not ordered
- ordinal – qualitative, ordered
- interval – quantitative, ordered
- ratio – quantitative, ordered, a "fixed origin" exists, usually expressed as a proportion or percentage

The choice of intensity measurement depends largely on:

- objectives of the study
- availability of money and personnel

Attribute	**Incidence**	**Severity**
Generally easiest and quickest to measure	x	
Generally more difficult and time-consuming to estimate		x
More appropriate for diseases that are fatal, or near fatal	x	
Generally, more accurate, precise and reproducible	x	
More appropriate if disease intensity is very low	x	
More appropriate if disease intensity is very high		x

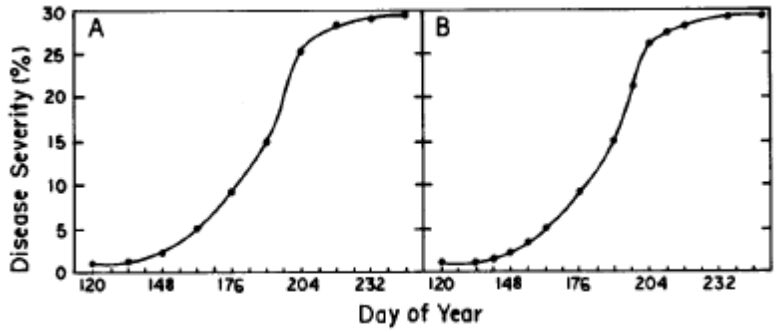
Timing and frequency of assessment depends on:

- how quickly disease is developing
- objectives of the assessment
- the need for a specific number of observations
- the need for observations during a particularly critical portion of the epidemic.

Time scales for disease assessments:

- calendar time
- physiological time (degree-days)
- host growth stage
- pathogen growth stage

Example: disease progress curves based on disease severity (percentage of diseased leaf area); similar curves for different observation intervals.



Visual assessment of disease severity

Most disease assessments in epidemiological studies rely on visual assessments

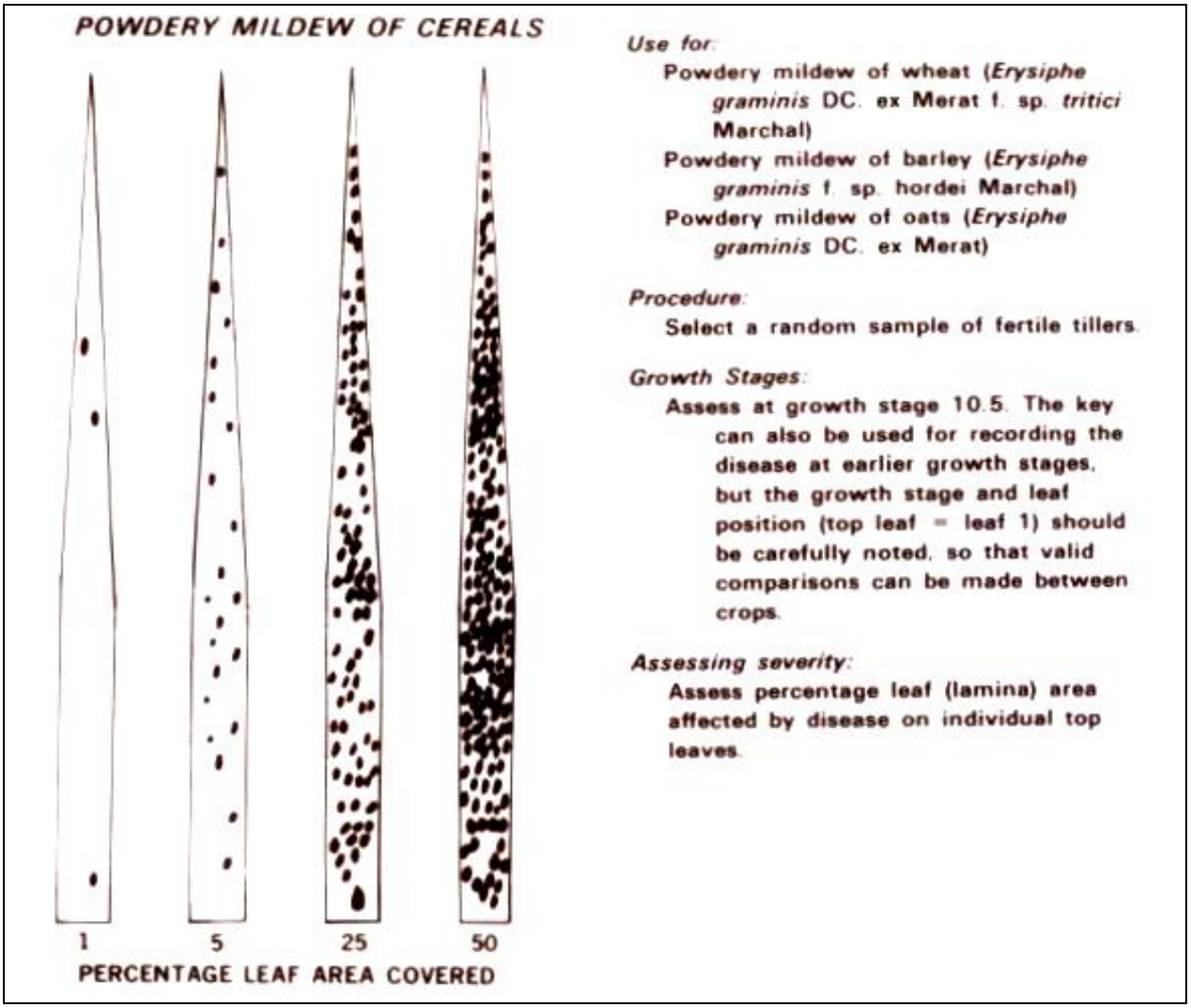
1. Direct estimation based on counting or measurement

2. Direct estimation with use of disease diagrams (= aids to assess disease severity, based on real values, not severity classes)

Cobb (1892)
- disease severity diagrams for cereal rusts, based on sketches of 1, 5, 10, 25, 50%

James (1971) - Manual of Assessment Keys
- includes several host growth stage diagrams.
- made for assessing disease on a single plant part
- much more difficult to estimate disease severity on a whole plant basis

Example: severity diagram for powdery mildew of cereals



3. Use of disease scoring scales

A disease scale is a partition of the continuous severity values from 0 to 100% into a finite number of classes (5-15).

Horsfall-Barratt Scale (1945)
Is a logarithmic scale, based on two assumptions (Weber and Fechner laws; not verified):
1. visual acuity is proportional to the logarithm of the intensity of the stimulus
2. the human eye focuses on diseased tissue when severity is <50% and on healthy tissue when severity if >50%; so, the largest error is in the centre of the scale.

According to Forrest Nutter, visual assessment is linear rather than logarithmic and raters can discriminate severity levels between 25% and 50% very well.

Because the scores are on a log scale, the ratings cannot be averaged or otherwise

analyzed directly using conventional statistical methods. The ratings must be converted to a percentage prior to analysis, using the midpoint method (arithmetic mean) or the Elanco formula (geometric mean), or non-parametric statistical methods can be used to analyze the rating data directly.

H-B Class	% Disease	Midpoint	Elanco Formula
0	0	0	0
1	0-3	1.5	2.34
2	3-6	4.5	4.68
3	6-12	9.0	9.37
4	12-25	18.5	18.75
5	25-50	37.5	37.50
6	50-75	62.5	62.50
7	75-88	81.5	81.25
8	88-94	91.0	90.63
9	94-97	96.5	95.31
10	97-100	98.5	97.66
11	100	100	100

Shortcomings of the H-B scale:

- Assumptions not true
- Classes overlap
- Back transformations are needed before statistical analysis

4. Use of ordinal rating scales

Most appropriate for systemic diseases, virus diseases, and root diseases

Example:

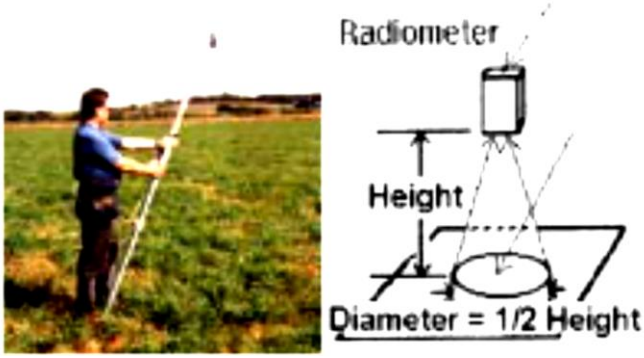
Rating	Description
1	Symptomless
2	Small root or stem lesions
3	Large root or stem lesions
4	Post-emergence damping-off
5	Pre-emergence damping-off

Remote-sensing

Techniques for measuring the characteristic manner in which a substance emits, absorbs, transmits or reflects electromagnetic radiation at some distance from the surface of that substance.

Based on the fact that crop canopies absorb and reflect incident radiation, and that healthy and stressed plants have different absorbance/reflectance characteristics (spectral signature) that can be measured quantitatively.

Multispectral radiometry (multiple wavelengths)
Measures near infrared (800 nm), in particular reflected light



The kind of instrumentation depends on distance between sensor and target

- low altitude (1.5-2.0 m above canopy) (hand-held sensor)
- intermediate altitude (75-1500 m) (airplane)
- high altitude (650-850 km) (satellite)

* Note that "ground truth" is essential for all remote sensing methods. What is measured is stress, and there can be various reasons for stress.

Electronic assessment of disease severity

Image analysis

- can be used to directly measure disease intensity
- enables the development of standard area diagrams for customized disease assessment keys
- for training of disease assessment

Indirect measurement of severity

- assessment of wilting or senescence for root diseases
- disease incidence measurements, based on quantitative relationship between incidence and severity (Note: relationship is likely to be nonlinear)

Attributes of a successful disease assessment scheme:

- reliable (reproducible)
- accurate
- describable

- efficient
- appropriate

Reliability = Precision:

- *intra*-rater reliability - the lack of variability in measurements when the same disease specimen is evaluated by the same evaluator
- *inter*-rater reliability - the lack of variability in measurements when the same disease specimen is evaluated by two different evaluators

Precision (lack of variability) is indicated by how close the points are to a regression line

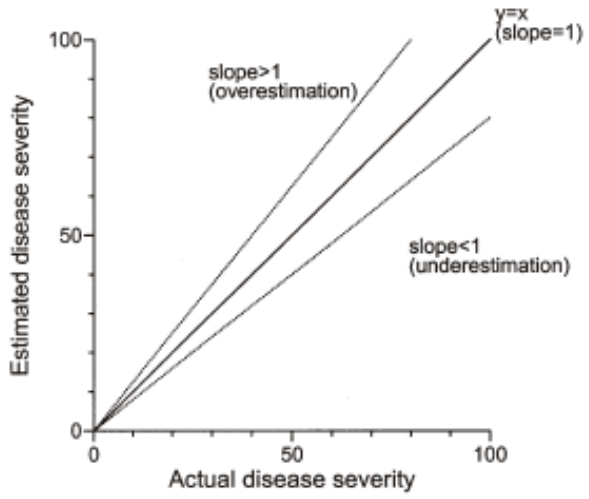
- is measured by the coefficient of determination (R^2) for the regression model. The higher the R^2, the better the precision.

Accuracy: the closeness of a measurement to the true value

Accuracy is represented by the closeness of the slope of the regression line to 1 and the closeness of the y-intercept to 0.
A slope that is significantly different from 1 indicates a significant bias (scale shift).

- If the slope of the line is greater than 1, the evaluator has over-estimated disease severity.
- If the slope of the line is less than 1, the evaluator has under-estimated disease severity.

An intercept that is significantly different from 0 indicates also a significant bias (location shift).



<u>Evaluating the accuracy and reliability of disease measurements</u>

Estimators can be asked to estimate percent disease represented by diagrams with known areas of disease; estimated values are regressed on the actual values

Describability:

- the method should be easily understood and unambiguous to all

- avoid vague terms such as *large, small, few, many, slight, moderate* and *severe*

Efficiency: quick, easy, inexpensive

Appropriateness: measurements should be appropriate for given disease and reflect the actual range of intensity levels

Illusions in disease assessment
Sherwood, et al. (1983) demonstrated that

- 9 out of 10 experienced estimators consistently overestimated disease
- overestimation was greatest when diseased area was smallest
- for 2 leaves with similar actual diseased area, the one with many small spots was perceived as having greater diseased area than a leaf with fewer, large spots.

There is a tendency for disease estimators to prefer certain values (1, 5, 10, 15%).
This results in an artificial "clumping" of data around these points