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Teaching botanical epidemiology at the Agricultural University, Wageningen[1]

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Abstract

Within the phytopathology curriculum the epidemiology teaching got its own place. A general outline of the curriculum, the prerequisites, and the courses is given, with details on the epidemiological courses. The student's opportunities for practice and research are indicated. Didactical notes are given. The objectives of epidemiology teaching in Wageningen are stated in terms of the intended terminal behaviour of the phytopatologist specialized in epidemiology.

> *Epidemiological analysis has come to stay. It welds together widely different observations into a coherent whole, and far more than any other way of thinking makes plant pathology a quantitative science. I believe that within a few years it will be taken for granted that it is as essential for a plant pathologist to be trained in epidemiology as it is for him to be taught mycology, virology, or genetics.*
>
> *J. E. van der Plank, 1963.*

Agricultural training at Wageningen in general

The Netherlands have only one agricultural college, situated at Wageningen. Teaching and research encompass agriculture in its widest meaning. Research, and teaching also, profit from the presence of numerous agricultural research institutes and services. Among these the Institute of Phytopathological Research (IPO) and the Plant Protection Service (PD) should be mentioned. Outside Wageningen, there is another centre of phytopathological teaching and research, the Phytopathological Laboratory 'Willie Commelin Scholten' at Baarn, which serves the Universities of Amsterdam and Utrecht, and the Free University, also at Amsterdam.

Scientific education in the Netherlands is changing rapidly. This paper reports on the situation in the academic years 1971/2 and 1972/3. The curriculum at the Agricultural University covers five years (Table 1), and leads to the title 'ingenieur' (shortened Ir.) which is roughly equivalent to the M.Sc. degree. Three or more years of continued

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Table 1. General outline of the curriculum at the State Agricultural University, Wageningen.

Year	Studies	Hours
1	basic sciences	1410
2	crop sciences	1600
3	specialisation	1600
4	practice	800
4,5	advanced studies	2400
6–8	Ph. D. research	pm

Explanation of symbols in Tables 1–16.

Year	– year of studies	– *studiejaar*
Hours	– study load in Study Hours, see Appendix 1.	– *studiebelasting in uren*
L	– lectures	– *hoorcolleges*
P	– practicals	– *practica*
S	– semester	– *semester*

Tabel 1. Overzicht van het curriculum van de Landbouwhogeschool.

Table 2. The science package of the first year.

Year	Basic sciences	Hours
1	biology	300
	chemistry	460
	economics	160
	mathematics	280
	physics	210
	total	1410

Tabel 2. De natuurwetenschappelijke propedeuse.

Table 3. The position of the *Crop protection* and *Phytopathology* courses in the crop science package of the second year.

Year	Crop sciences	Hours
2 S1	basic sciences (continued)	
	crop sciences	
	Crop protection	40L
2 S2	crop sciences entomology	
	Phytopathology	80L + 80P
	total	1600

Tabel 3. De plaats van de onderwijselementen Gewasbescherming en Fytopathologie (Plantkundig deel van de planteziektenkunde) in het curriculum van de teeltrichtingen, in het tweede studiejaar.

research devoted to a single problem may lead to a doctor's title, equivalent to the Ph. D. degree.

In the first year, the students (about 900) can choose one of three course packages: science (Table 2), science and humanities, or biology (which differs somewhat from science for various reasons). In the first semester of the second year, the science students (about 600) have the following options: crop sciences (Table 3), zoötechnique, technical and soil sciences, and chemical and technological sciences. About a hundred students take the crop science package, including a short course in *Crop protection.* In the second semester the crop science students have six options: field crop husbandry, horticulture, tropical crop husbandry, crop protection, plant breeding, and forestry. For most of the crop science students the *Phytopathology* course is compulsory. In the third year, the students have great freedom to compose their own course packages by selecting from all courses offered. The courses taught in the Department of Phytopathology can be regarded as optional (Table 4); one or more are taken by all crop protection students (about 25), and by many other crop science students (mycology 10 to 20, others 20 to 40).

After three years of courses, terminated by an intermediate examination, the 'kandidaats-examen' at B. Sc. level, the students spend one half year in practice, at

Table 4. Courses taught by the Laboratory of Phytopathology to crop science students in their third year.

Year	Specialisation	Hours
3	options:	
	Epidemiology	80L + 80P
	Mycology	40L + 40P
	Physiology of parasitism	80L + 80P
	Phytopathological Techniques	80P
	total	1600

Tabel 4. Onderwijselementen aangeboden door de vakgroep Fytopathologie aan derdejaars studenten in de teeltrichtingen.

Table 5. Advanced courses offered by the Laboratory of Phytopathology.

Year	Advanced courses	Hours
4,5	options:	
	Aerobiology	40L
	Crop losses	40L
	Ecology of pathogenic root-infecting fungi	80L
	Fungicides	60L
	Resistance (genetical)	80L
	Resistance (physiological)	80L
	Quantitative epidemiology	80L
	total	2400

Tabel 5. Onderwijselementen aangeboden door de vakgroep Fytopathologie aan de doctoraalstudenten.

university departments, agricultural research stations, chemical industries, etc., in the Netherlands (55%) or abroad (45%), often in the tropics (30% in 1972). This period gives the students a broader outlook on the application of science. Each student has to write a report; some students then do their first scientific research.

In the fourth and fifth year, the students specialize in (usually) three topics. In each they take courses and do some research. The Laboratory of Phytopathology offers a series of advanced courses, in roughly a two-year rotation (Table 5). Research subjects are offered in the same areas as the advanced courses. Research subjects take 1 to 3 units of three months, during which students spend half of their time on research and half on course-work.

Basic phytopathology teaching

In Wageningen, current thinking on curricula in the biological sciences concentrates on three so-called integration levels. These are the level of cellular processes, the level of the individual, and the level of the population. Phytopathology teaching centers largely on two levels: the level of the cellular processes with the reaction of the individual as the end result, and the level of the population with the individual as the starting point. The two integration levels meet in the individual host plant and its reactions to pathogens.

Teaching and research in the crop protection sciences are distributed over four departments: Entomology, Nematology, Phytopathology and Virology. Notwithstanding its name, which has historical reasons, the Department of Phytopathology is concerned with fungal and bacterial diseases only. At the integration level of the population there is, in accordance with common usage, a separation between the

Table 6. The hierarchy of prerequisites in epidemiology teaching.

Year	Courses
2 S1	*Crop protection*
2 S2	*Phytopathology*, L + P
3	*Epidemiology*, L
	→ *Epidemiology*, P
4,5	*Quantitative epidemiology*
	Aerobiology
	Crop losses
	Resistance (genetical)

Tabel 6. De voorvereisten bij het epidemiologie-onderwijs.

pathology of the roots and that of the shoots. Only the latter is named *Epidemiology* s.s. In teaching botanical epidemiology (Zadoks, 1974), it is customary to compare with or use examples from medical and veterinary epidemiology, entomology, nematology and virology, and soil-borne pathogens.

For the present purpose, the various courses taught show a hierarchy of prerequisites (Table 6). At the base is the *Crop protection* course which is at the population level. Crops are dense populations of plants, which must be protected against populations of injurious agents, be it fungi or nematodes, viruses or insects (Table 7). Crop protection is seen as the art of manipulating populations by agricultural practices, sanitation, chemical control, and biological control. Mention of specific pests or diseases is avoided, but *Puccinia graminis*, *Leptinotarsa decemlineata* and *Heterodera rostochiensis* appear regularly to serve as connecting threads and memorial aids. The *Crop protection* course is an introductory course for all students in the field of crop sciences, and at the same time it is the final course in crop protection sciences for some of them.

The *Phytopathology* course (Table 8) is a concise course on fungal and bacterial plant diseases, arranged according to two guiding principles, fungal taxonomy and types of diseases (fleck-diseases, wilt-diseases, etc.). The course is compulsory for most students in the crop sciences, and it is a final course for some of them. Epidemiological aspects are treated briefly, and in an exemplary way: *Phytophthora infestans* standing as the example for the *Peronosporales*, etc.

Table 7. The introductory *Crop protection* course.

Year	Crop protection	Hours
2 S1	scientific viewpoint: *Population dynamics* social viewpoints: *1. State* *2. Consumers* *3. Growers* *4. Industry*	40L

Tabel 7. Het inleidende onderwijselement Gewasbescherming.

Table 8. The *Phytopathology* course.

Year	Phytopathology	Hours
2 S2	scientific viewpoints: *Taxonomy* *Types of diseases* *Etiology* *Control* subject matter: *Fungi, Bacteria*	80L + 80P

Tabel 8. Het onderwijselement Fytopathologie (Plantkundig deel van de planteziektenkunde).

Epidemiology teaching

The development of epidemiology as a special branch of phytopathology was greatly stimulated by professor Oort, former head of the department (Zadoks and Dekker, 1969). The present *Epidemiology* course in the third year of studies is a course in applied ecology. The course in *Phytopathology* serves as a prerequisite, providing the necessary factual knowledge on plant diseases. The *Epidemiology* (Table 9) course concentrates on processes. It is roughly divided in three parts: autecology, synecology and methodology. The autecological part treats the effects of temperature, water and radiation on a number of fungal and pathological processes. A section on 'time as a variable', ending with a discussion on 'sequential analysis', forms the transition to the synecological part of the course. Here, the leaf surface, the soil, and the crop are discussed as typical ecosystems of transient nature, and the air-borne dispersal of pathogens is treated. The mutual effects of crop, pathogen and non-pathogenic micro-organisms are emphasized. Where possible, the relation between weather, microclimate and physiological processes is demonstrated. The methodology part discusses the why-and-how of epidemiological experiments, the merits of field versus growth-cabinet experiments, and the mathematical expression of the experimental results. The non-compulsory practical serves as a demonstration of the phenomena discussed, and for practicing the methods taught.

Table 9. The *Epidemiology* course.

Year	Epidemiology		Hours
3	scientific viewpoints:	*Autecology*	
		Synecology	
		Mathematical relations	
		Methodology	
	subject matter:	*Radiation, Water, Temperature*	
		Leaf, Root, Crop	
		Dispersal	
		Time	
			80L + 80P

Tabel 9. Het onderwijselement Epidemiologie.

The advanced courses are taught once in two to three years. Their function is to deepen the insight of students in chosen chapters of phytopathology. Active participation from the part of the students is requested and stimulated by questions, problems and study of indicated litterature. The course on *Resistance (genetical)* (Table 10) has an epidemiological background, but is not epidemiology as such. The course on *Aerobiology* (Table 11) teaches in detail the aerial dispersal of plant diseases, largely following Gregory's book 'Microbiology of the atmosphere' (1972). Emphasis is laid on the physics of the dispersal process. The *Crop losses* course (Table 12) can be regarded as the economic and social end-point of epidemiology teaching. Starting with the physiological aspect, the relation between root and shoot damage, the course treats the assessment of injury, of loss in yield and/or quality, and of financial losses. Cost-benefit ratio's of various control methods are discussed. The *Quantitative epidemiology*

Table 10. The *Resistance (genetical)* course.

Year	Resistance (genetical)		Hours
4,5	scientific viewpoints:	*Genetics of resistance and virulence*	
		Man-made evolution	
		Strategy of resistance breeding	
	subject matter:	*Differential resistance*	
		Variability } *in host and*	
		Gene identification } *pathogen*	
		Uniform resistance	
			80L

Tabel 10. Het onderwijselement Resistentie (genetisch).

Table 11. The *Aerobiology* course (Aerobiological aspects of botanical epidemiology).

Year	Aerobiology		Hours
4,5	scientific viewpoints:	*Physics of dispersal*	
		Form and function	
	subject matter:	*Convection, turbulence*	
		Take off, flight, landing	
		Sampling techniques	
			40L

Tabel 11. Het onderwijselement Aerobiologie (Aerobiologische aspecten van de botanische epidemiologie).

Table 12. The *Crop losses* course.

Year	Crop losses		Hours
4,5	scientific viewpoints:	*Physiology of losses*	
		Methodology of loss assessment	
		Economic and social aspects	
	subject matter:	*Loss in single plants and crops*	
		Injury, damage and loss assessment	
		Cost-benefit relations	
			40L

Tabel 12. Het onderwijselement Schade.

course (Table 13) begins where the prerequisite course on *Epidemiology* ends: mathematical expressions for relations between variables. Various types of epidemiological models are discussed, beginning with the differential equations, and ending with simulation models. The usefulness of models to illustrate certain points of epidemiological theory is demonstrated, more or less in the track of Van der Plank's 'Plant diseases, epidemics and control' (1963).

Table 13. The *Quantitative epidemiology* course.

Year	Quantitative epidemiology		Hours
4,5	scientific viewpoints:	*Quantification of variables*	
		Quantification of relations	
		Quantitative models	
	subject matter:	*Differential equations*	
		Simulation techniques	
		Possible applications	
			80L

Tabel 13. Het onderwijselement Kwantitatieve epidemiologie.

Student research

After their 'kandidaats-examen', the phytopathology students take one to three research subjects. Some 10 students a year choose an epidemiological topic, usually one out of the following list:
- Epidemiology of *Puccinia recondita*, *P. striiformis*, or *Septoria nodorum* on wheat.
- Physiology of crop losses in wheat, caused by *P. recondita*, *S. nodorum*, moisture stress, or combinations of these.
- Aerobiology of *Sphaerotheca pannosa* or *P. recondita*.
- Uniform resistance of wheat against *P. recondita*.

Students are free to choose their topic and their approach, when possible. After a few introductory discussions with his tutor, the student has to write his own research proposal, with time schedule, and list of materials to be used. After discussion and approval of the research proposal, the student starts to work, receiving advice, technical assistance, and equipment when needed. At the end of his stage, the student presents a verbal account of his work to staff and research students, and writes a detailed research report. Some of the students' results are published in due time. In one instance, the research has been done by a problem-centred ad-hoc group of some 10 students, who selected their own subject. When it is allowed to judge by one experience only, these problem-centred student groups are very demanding on the teacher, asking more hours per student than ordinary individual supervision does. The experience of functioning in a social group with individual as well as common tasks is quite valuable to Dutch students, who tend to be rather individualistic (Rijsdijk and Zadoks, 1970; Van den Bos, e.a., 1971).

Ph. D. research

In the Netherlands Ph. D. candidates are junior members of the scientific staff and not students. They devote a period of three years (or more) to a single research subject with the aim of developing their scientific outlook and skill, and extending the field of knowledge. The publication of the results in one book (thesis) or a number of scientific papers is an essential part of the Ph. D. work, and not infrequently the writing-up is the toughest part. The teaching is tutorial, according to the individual needs without obligations for course work. Typical doctors' theses in epidemiology

are those of Turkensteen (1973), van der Zaag (1956) and Zadoks (1961); others are in preparation.

Samenvatting

Onderwijs in de botanische epidemiologie aan de Landbouwhogeschool te Wageningen

De Wageningse opleiding duurt vijf jaar (Tabel 1). Na een natuurwetenschappelijke propedeuse (Tabel 2) kan men zich in het 1e semester van het 2e jaar richten op de teeltvakken (Tabel 3) en in het 2e semester specialiseren in de planteziektenkunde. In het 3e studiejaar kunnen de studenten hun eigen studiepakketten samenstellen, waarbij o.m. gekozen kan worden uit de onderwijselementen (cursussen) aangeboden door de vakgroep Fytopathologie (Tabel 4). Hetzelfde geldt voor de doctoraalstudie (Tabel 5). Voor sommige onderwijselementen gelden voorvereisten (Tabel 6). De inhoud van de meer epidemiologisch gerichte onderwijselementen wordt aangeduid in de tabellen 7 t/m 13. 'Projectonderwijs' bleek mogelijk maar vergde veel docentetijd. Er bestaat gelegenheid tot leeronderzoek en promotieonderzoek in epidemiologisch gerichte onderwerpen binnen de fytopathologie. Appendix 1 vermeldt een aantal didactische gegevens. In appendix 2 worden de doelstellingen van het epidemiologie-onderwijs verwoord in termen van het beoogde eindgedrag van de epidemiologisch gespecialiseerde fytopatholoog.

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Appendix 1: Didactical notes

1. In Wageningen, the student's work load is measured in Study Hours. The average student is expected to work during 1600 Study Hours per year. A Course Unit is 12 teaching hours of 45 minutes

each, which is supposed to be equivalent to 40 Study Hours, including attendance to the lectures (or practicals), work at home, and preparation for examinations (a Course Unit is more or less equivalent to one American Credit Point).

2. Teaching aids are cyclostyled course books, slides in black and white or color, and films (*crop protection* course only). The measuring instruments are demonstrated during the lectures. Sometimes, a field visit replaces a lecture.
3. After some of the lectures the students can test their ability by solving problems. The examination is preferably in written form, by means of problems and/or multiple choice questions.
4. Students like to learn problem solving in the following way: the teacher explains a (historical) situation as it occurred in practice, leaves the students for some time to think up various solutions, then organizes these solutions into a general scheme, and finally tells which solution has been adopted in practice, and why.
5. The following course books on epidemiology and related subjects are available (in Dutch, cyclostyled):

   Year

   2 S1 Zadoks, J. C.: Crop protection.
   2 S2 Dekker, J.: General phytopathology.
   3 Frinking, H. D., Zadoks, J. C.: Epidemiology.
   4/5 Van der Wal, A. F., Zadoks, J. C.: Resistance (genetical).
   Zadoks, J. C.: Aerobiological aspects of botanical epidemiology.
   Zadoks, J. C.: Quantitative epidemiology.
   Zadoks, J. C.: Crop losses.
6. The following films (16 mm, color, optical sound track) are shown in the 2 S1 Crop protection course:
   - Plant pests and diseases, brown rot (*Sclerotinia fructigena*). Shell film, English, 14 minutes.
   - The black bean aphid (*Aphis fabae*). Ministry of Agriculture, the Netherlands, Dutch, French or English, 21 minutes, 1962.
   - Eelworms. Ministry of Agriculture, the Netherlands, Dutch or English, about 10 minutes, 1969.

Appendix 2: Objectives of epidemiology teaching as indicated by the intended terminal behaviour of the phytopathologist specialized in epidemiology

Explanation of symbols:

L = taught in lectures
P = taught in practicals
T = taught by individual tutoring during research subject
x = implicit objective of teaching (mainly discussed during coffee breaks).

Year 2S1 – Crop protection

1. A general notion of the various threats to plant production L
2. A general insight in the social mechanisms, present techniques, and future possibilities to oppose these threats. L
3. An ability to read newspapers and non-specialized agricultural publications critically with respect to crop protection problems.
4. A balanced judgement with respect to actual ethical problems, like crop protection versus environmental pollution, and private enterprise versus public care. L
5. The ability to choose one among six crop science options. x

Year 2S2 – Plant pathology

1. A general knowledge of
   a. the taxonomic groups of plant pathogenic fungi, L + P
   b. the symptomatic groups of diseases caused by fungi, L + P
   c. the etiology of plant diseases caused by fungi and bacteria, L + P
   d. the epidemiology of fungal plant diseases as demonstrated by a few representative examples, L
   e. the control of fungal and bacterial plant diseases. L

2. The ability to consult text books and general handbooks, and to understand phytopathological papers of a general nature. P
3. The ability to describe a plant disease and its symptoms. P
4. The manual abilities of
   a. dissecting diseased plants for macro-and microscopical examination, P
   b. isolation of the causal organism, P
   c. giving proof of causality by the application of Koch's postulates, P
   d. identification of causal organism at the taxonomic level of order, family, or sometimes genus. P
5. The ability to choose a further specialization in the field of plant pathology. x

Year 3 – Epidemiology

1. A general knowledge of
   a. epidemic processes, L
   b. epidemiological measuring techniques, L + P
   c. epidemiological calculation methods. L + P
2. A general notion of 'problem shooting'. L
3. The manual ability of
   a. crop measurement techniques, P
   b. disease assessment methods, P
   c. physical (meteorological) measuring techniques, P
   d. spore trapping methods, L + P
   e. resistance testing, P
   f. race identification. P
4. A general ability to perform simple epidemiological calculations, using mathematical methods. L + P
5. The ability to read specialized epidemiological text books (in at least one foreign language). x
6. The ability to read simple specialists' papers on epidemiological subjects (in at least one foreign language). x

Years 4 and 5 – Advanced courses and research subjects

1. Specialized knowledge in chosen chapters of phytopathology, including epidemiology. L
2. Detailed knowledge of the methodology of epidemiological research. T
3. The ability to read and utilize specialistic epidemiological papers (in at least one foreign language). x
4. Ability to utilize information and techniques from other fields of science (mathematics, physics, agronomy, etc., etc.) in problem solving. L + T
5. Skill in devising, planning, performing, and reporting small-scale epidemiological research (subject size: about 3 months). T

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