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A hundred and more years of plant protection in the Netherlands

J.C. ZADOKS

Department of Phytopathology, Wageningen Agricultural University, P.O. Box 8025, 6700 EE Wageningen, the Netherlands

Abstract

At the occasion of the Centenary of the Netherlands Society of Plant Pathology a reflection on past, present and future of plant protection, the subject matter of the Society, was thought to be appropriate.

Developments in plant protection are projected against a general stream of thought. Three turning points are distinguished which can be seen as paradigm changes. The first occurred around 1890, when the concept of pathogenitism gained its final victory over autogenitism. The second occurred around 1940, when the public outlook on human and plant health changed drastically due to the advent of chemotherapeutants. The third occurred around 1990 when a clear change in public thinking on agriculture, environment and plant protection became apparent. The background of these changes is sketched in a personal manner.

Some ideas on plant protection beyond the year 2000 are given, based upon recent developments in the Netherlands to which the Society contributed in its own way.

Key words: Crop protection, environmental protection, paradigm, pest management.

1 Introduction

During a full century, the Netherlands Society of Plant Pathology, founded on 11 April, 1891, has been the very embodiment of Dutch plant protection. The members of that society, being citizens of the Netherlands and of the world at large, followed the main stream of thought during that century and sometimes contributed to that stream. Society and plant protection, plant protection and society (Zadoks, 1989a), they interact. These interactions are the subject of the present paper submitted to honour the centenary of the world's oldest plant protection society.

The following is not an official historiography nor a philosophical treatise. It has no pretension but the recording of some reflections by a thoughtful scientist with a bias to phytopathology who, though sometimes called to administrative duties, nevertheless feels an observer at heart.

2 Scientific episodes

2.1 Paradigm changes

Science is made by people. As people are subjected to gradual and sometimes to sudden changes in trends of thought, science is too. Some changes in scientific thinking may not only be sudden but even radical, as if the stream of thought has chosen a new bedding. Then, well established 'facts' are seen in a new light, their appearances change, and unexpected scientific progress becomes possible. Such changes have been indicated as changes of paradigm (Kuhn, 1970). Paradigm has the connotation of a way to look at things, the spectacles through which the scientist views reality. The span of time during which reality was seen in a recognizable way is here, lightly, called an 'episode'.

In olden times pests and diseases were considered to be inflicted upon mankind as a punishment of the gods. Remnants of this view can still be found in some rather recent textbooks, such as Stakman and Harrar (1957, p. 541), who stated 'The ultimate aim of plant pathology is to banish destructive plant diseases'. In the 18th century this view was already questioned, when the movement later called 'enlightenment' tried to disentangle scientific and religious views on reality. One example of the entanglement of religious and scientific thinking: official views still favoured the concept of *generatio spontanea*, though some researchers disbelieved (among whom the Dutch microscopist Van Leeuwenhoek, 1632-1723, and the Italian biologist Spallanzani, 1729-1799).

The change came about very gradually at first. Pioneer pathologists in the 18th century, such as Duhamel de Monceau (1728, see Zadoks, 1981) and Targioni Tozzetti (1767, see Targioni Tozzetti, 1952), were forgotten, probably because their results and conclusions did not fit in with current official thought. In contrast, Fontana (1767, see Fontana, 1932), who considered black stem rust as a consequence of disease and not as a cause, was much quoted.

In the 19th century, a fierce battle was fought between autogenitists and pathogenitists (Whetzel, 1918). The issue was, in brief, whether pathogens are the cause or the consequence of disease. Fighting over the potato murrain, Berkeley was the protagonist of pathogenesis, Lindley of autogenesis (Large, 1950). De Bary's (1861, 1863) evidence in favour of pathogenesis was accepted as decisive. Scientists and public became really convinced, however, after the experiments of Pasteur (see Large, 1950) and Koch in the late 19th century. The new paradigm, pathogens are the cause of disease, is succinctly phrased in Koch's (1891) 'postulates', explained to a scientific audience in 1890. The interference of these scientific giants set the rules of thought: pathogenesis is *it*.

During the long interval between Van Leeuwenhoek and Ritzema Bos (1850-1928), *the Dutch plant protection scene* was rather dull. Most of the activity was parochial, and its scientific value slight. People of some influence appeared at the end of the 19th century, rather as precursors of the next episode.

2.2 The pathogenitist episode

It is not accidental that the Netherlands Society of Plant Pathology was founded in 1891 (Table 1). In medicine and in crop protection, the new ideas gave new hope to cure the world from pests and infectious diseases. Medical practitioners and crop protectionists alike saw new prospects for the development and application of their respective sciences. The foundation of a professional society is a way to unite forces to attain a common goal, development and application of science. The foundation of the Society

Table 1. Presidents of the Netherlands Society of Plant Pathology.

1891 - 1896	J.H. Krelage
1896 - 1929	Prof. Dr J. Ritzema Bos
1929 - 1933	H. Lindemans
1933 - 1937	Prof. Dr W.K. Roepke
1937 - 1946	Prof. Dr H.M. Quanjer
1946 - 1951	Prof. Dr J.G. ten Houten
1957 - 1963	Dr P.M.L. Tammes
1963 - 1970	Dr H.J. de Fluiter
1970 - 1975	Dr N. van Tiel
1975 - 1981	Ir M. Heuver
1981 - 1987	Dr Ir A.M. van Doorn
1987 -	Dr Ir P. van Halteren

coincided approximately with the most clear-cut change of paradigm known in the science of crop protection. For this coincidence is chosen, somewhat arbitrarily, the year in which Robert Koch pronounced his 'postulates', the year 1890.

The science of plant protection was placed on another footing. Injury was due to a harmful agent (pest or disease organism, or environmental factor); the injury should be reproducible experimentally by exposing plants to that harmful agent. Remedies against pests and diseases were to be based on an objective analysis of cause and effect. The search for pathogens to explain disease has continued ever since. This is Kuhn's (1970) 'normal science' during the pathogenitist episode. One practical consequence of the new view was that infection or infestation was to be avoided as much as possible by all kinds of hygienic measures. In medicine, hygiene as an approach to avoid contagious disease had been developed empirically throughout the 19th century. Crop protection followed suit. Plant quarantine was introduced and plant protection laws were established (Table 2). Extension and regulatory action were tuned accordingly.

More or less coincident with, and certainly not independent of the pathogenitist theorem are the beginnings of chemical control. Millardet's (1885 ex Schneiderhan, 1933) finding, the Bordeaux mixture, became widely applied around 1890.

Let us quote some specifics from *the Dutch scene*. Among the founding fathers of

Table 2. Chronology of acts and decrees on crop protection in the Netherlands.

1875	Act on measures to take against the transmission of the Colorado-beetle
1883	Act on the execution of the international treaty of Berne, 3 november 1981, to avert Phylloxera vine-pest
1889	Act with measures to avert organisms harmful to agriculture, horticulture or forestry, and of plant diseases
1899	Decree on the organization of the Phytopathological Service (= present Plant Protection Service)
1910	Act with regulations to avert American gooseberry mildew
1914	Act with regulations to avert potato diseases
1951	Plant Diseases Act
1962	Pesticides Act

the Wageningen Agricultural University and today's Agricultural Research Department (DLO) were Beijerinck, Mayer and Ritzema Bos. Ritzema Bos was the most impressive scientist and personality, the founder of the Society and its journal 'Tijdschrift over Plantenziekten', now 'Netherlands Journal of Plant Pathology' (NJPP). A zoologist by training, he engaged in entomology, nematology, phytopathology and air pollution (dust, SO_2) (Bieleman, 1987; Rapport, 1902; Ritzema Bos, 1891); he was the Netherlands' first science-based plant protection extensionist, regulatory agent, and university professor (Amsterdam, 1895; Wageningen, 1906). He founded the Dutch Plant Protection Service in 1899. Mayer (1886) studied tobacco mosaic disease and Beijerinck (1898) contributed to the foundations of virology by postulating his *contagium vivum fluidum*, now briefly 'virus'. Resistance breeding came into being, in the 19th century as an empirical exercise, since Biffen (1908) as a scientific endeavour. The Wageningen-based Broekema scored his first breeding successes (barley cv. Vada, wheat cv. Wilhelmina).

The detection of more and more viruses, against which there was resistance nor cure, led to the scientific development of hygiene by way of seed certification. Quanjer (1879-1961), Oortwijn Botjes (1878-1964) and Van Slogteren (1887-1967) constructed the scientific foundations of the certification services (seeds and planting stock) in the Netherlands, thus promoting the Dutch seed potato industry, flower bulb trade, and export of ornamentals, all flourishing ever since (Brust, 1958; De Bruyn, 1961; Rozendaal, 1965; Schenk, 1968).

Even around 1890, it was realized that pathogenesis is not the whole story. The environment must be suitable to give the pathogen an opportunity to develop (Marshall Ward, 1901; Jones, 1913). At the time, the role of environment was strongly advocated by entomologists. Taking the environmental view serious implies that the methodological primate of the pathogen, as exemplified in Koch's postulates, is little more than a tacit agreement, unchallenged only for the sake of practicality (Zadoks, 1978). In other words, it is a way to look at reality, silently agreed upon in the scientific world, a paradigm.

2.3 *The chemotherapeutant episode*

A change of mentality among the public, scientists included, became noticeable around World War II, when chemotherapeutants became available, in medicine first, in crop protection later. The medical profession honestly believed that immunization and chemotherapy had brought most contagious diseases under control, and the general public relied on that view. Sociological studies demonstrated that this view was, at best, partially correct. In the public eye, penicillin – the miracle drug – did it. Fleming (1929) is rightly homaged, as his work led to the American war-time patents. The independent Dutch patents (Elema, 1970), based on *Penicillium* cultures from the 'Centraal Bureau voor Schimmelcultures' at Baarn (CBS), might be traced back in part to the pioneer work of the Dutch phytopathologist Van Luijk (1938).

The confidence of the public in pills, powders and parenteral injections increased after the Second World War. Chemical and pharmaceutical industries boomed. In the western world, contagious human diseases and dreadful secondary infections were practically eliminated by immunization and antibiotics. Disease was no longer felt as a continuous threat to human existence but rather as a temporary inconvenience with nuisance value only. Reliance on pharmaceuticals lured people into neglect of hygiene during the late 1960s and the 1970s. New habits spread, particularly among teenagers. The long hair style, the neglect of personal hygiene, and frequent interchanges of cloths promoted epidemics of head lice in schools. The newly acquired sexual freedom induced epidemics of pubic lice, hepatitis b, herpes genitalis, and – much later – AIDS.

With the wisdom of hindsight, we may say that a new view on health and disease, a new feeling of life, with new attitudes in everyday life was created or at least facilitated by the positive effects of chemotherapeutants and their wide-spread availability. In the western world, emphasis was placed on curative medicine, at the expense of preventive medicine. Though the new view crept upon mankind very gradually, its impact was enormous. The change in perspective, among the medical profession as well as among the general public, can be seen as a profound change in mentality and outlook, a change of paradigm. A date for this change, admittedly arbitrary, could be 1940, when sulphanilamides were already and penicillin was not yet available.

In plant protection, the situation was comparable to that in medicine though it developed with some delay. The similarity is in the heavy reliance of modern agriculture on pharmaceuticals, plant protection chemicals, or pesticides. Pesticides came into use first as protectants, then as curatives, finally as prophylactics. At times they were used, or abused, as an insurance premium (De Tempe, 1958) or to feel safe and quiet. Agriculture manoeuvered itself into this dependency, happily though not completely out of free will, because the changing economics of farming dictated the move.

In the western world, the 'green revolution' began shortly after World War II (De Wit et al., 1987). In the graphs it appears as a sudden increase in the annual yield increments. The green revolution in the tropics began some 20 years later with the 'miracle rice' IR8 and its corollaries, irrigation, fertilization and chemical crop protection. In the west and in the tropics, the availability of external inputs, fertilizers and pesticides, contributed to the change then widely acclaimed.

The Netherlands, after World War II, were obsessed by the food shortages they had suffered. Agriculture was reconstructed, and Marshall Aid funds were used i.a. to stimulate agricultural research. The Dutch Miracle came into being, an incredible boost in production efficiency (in kg man^{-1} hr^{-1}). The economic pressures on Dutch agriculture became such, that growers had to specialize. Mixed farming was given up and rotations were narrowed. The pressure for high yields led to high fertilizer levels, and these in turn induced higher risks of damage due to pests and diseases. These changes increased the dependance on pesticides.

Field crop rotations narrowed down and necessitated soil treatments (Oostenbrink, 1950). In greenhouses nearly continuous monocropping became the rule. Drastic disinfection became necessary when natural soil formed the plants' substrate. For some foliar pests and diseases, conditions became optimal so that intensive chemical control was needed. Cheap herbicides replaced expensive labour and tillage. Around 1970, the advent of systemic pesticides lulled many growers into negligent quiescence because most pests and diseases could be chemically remedied when prevention had failed.

The behaviour of growers and their advisers, including agricultural scientists, unconsciously may have been influenced by the common attitude to human health. Presumably, the change in mentality toward human health and disease has affected the thinking on crop protection, and thus has stimulated the move toward pesticide dependency.

Though the actual change in outlook and mentality was so slow as to be nearly imperceptible, except maybe in pesticides sales figures, it was so profound and it had such important consequences, that I don't hesitate to call it a change of paradigm. It did not change older truths, but gave them a different perspective. Not the real world changed so much, but the perception of that world with its promises and risks altered drastically. In my view, the 1940 change of paradigm deeply affected crop protection, where prevention and hygiene were neglected and the curative attitude became preponderant.

During this episode, Dekker was one of the leaders in a prominent area, the mode of action of systemic fungicides. Specificities (Bollen and Fuchs, 1970) and side effects were studied (Bollen, 1985). Some of their commercial disadvantages became apparent such as resistance of a pathogen to an active ingredient, for which Dekker (1969) gave an early warning, and these resistances were thoroughly studied (Dekker, 1987; De Waard et al., 1986). Subsequently, the concept of resistance management (resistance in the sense of resistance of a fungus to a fungicide) was developed (Dekker, 1986; De Waard et al., 1986; Schepers, 1985). Biocidal action of natural substances was studied too (Gommers et al., 1980). Crop protection on a more ecological basis, though actively pursued, rather remained an understream of the crop protection research of that episode, except – maybe – in entomology.

2.4 The new-environmentalist episode

The next large change in the attitude and mentality of the public at large crept upon us very gradually at first, then picked up speed. It began as an environmentalist movement, elsewhere called the 'third wave of holistic tendencies' (Zadoks and Koster, 1976). In crop protection, the early environmentalist movement, kindled by 'Silent Spring' (Carson, 1962), was a very emotional movement, romantic nearly, though it had strictly rational foundations. The new-environmentalist movement is its successor, far more matter-of-fact, science-based, cool, even cunning, and supported by a well-planned strategy. The result today (1990) is a strong environmental consciousness of the general public.

In the Netherlands, the roots of change are many. Dutch entomologists contributed to the debate since World War II. The beginning was slow. Voûte (1946), Kuenen (1948) and Briejèr (1949) expressed their doubts on chemical pest control, at a time when synthetic insecticides were introduced recently. Briejèr (1967) added gloom to 'Silent Spring' in his own morose way. Two prominent entomologists, De Wilde and Kuenen, coined the concept of 'harmonious control'. This concept was near-identical to the 'integrated control' of Pickett et al. (1958), but developed independently during (post-) wartime scientific isolation. In 1956, De Wilde established a committee on harmonious control, which in 1958 obtained formal status and funding as the 'Working Party on Integrated Control' (Minks and Gruys, 1980), which became quite influential. Though a first attempt at integrated pest control in orchards met with little success, it prepared the ground for present day developments which are promising.

'Organic farming', long fostered in anthroposophic circles, became vociferous in the 1960s. 'Ecological farming' followed with the same intentions but without the typical philosophical context. Action groups appeared and some became highly respectable, such as the 'Centre for Agriculture and Environment' (Centrum Landbouw en Milieu, Utrecht). One group forwarded the notion of 'integrated agriculture', the near-equivalent of 'sustainable agriculture' in the USA. In 1984, the Scientific Council of Government Policy supervised the publication of a policy paper 'Integrated Agriculture' (Van der Weijden et al., 1984), which turned an unspeakable subject into a fashionable topic in Dutch political circles. 'Agriculture, should it turn a corner?', that was the question (Zadoks, 1987).

Dutch nematologists of international fame, Oostenbrink (1950) and Seinhorst (1965), stimulated crop rotation research for nematode pest management. The Netherlands have gained a leading position in biological control of protected crops (Van Lenteren and Woets, 1988). Dutch road verges, once maintained like golf links at great expense and so satisfying the esthetic ideal of some superintendent but terribly boring the passer-by, are full of flowers and flower-visiting insects again thanks to the far cheaper ecological management practices advocated by Zonderwijk (1982).

Vociferous criticists, at last echoed in Parliament, pressed the Ministry of Agriculture to initiate a series of studies (Committee, 1974 and 1977) and, eventually, to take action. In 1980, it began a large experiment in farming systems comparison and development with a Current Farm, an Integrated Farm and an Organic Farm with, respectively, high, low and no external inputs (Zadoks, 1989b). The abstract concept of 'Integrated Agriculture' was given bones and meat on the Integrated Farm. The tireless efforts of Vereijken (1989) and later Wijnands contributed to the success.

Several developments in the Netherlands added to a feeling of crisis. Among them were (1) the food surpluses in the European Community and the great public costs to regulate them, (2) the high pollution level of air, soil and water, (3) the increased public awareness of human, animal and environmental health risks, and (4) the change in attitude of consumers who not only require high food quality (free from pesticide residues) but also high quality of food production ('natural', that is with few external inputs). These events led to a change of thinking: environmental pollution should be avoided even at the expense of economic growth. In 1989, the Ministry of the Environment began a hard campaign and the Ministry of Agriculture followed, as evidenced by a set of policy papers (Table 3). As of 1990, the public welcomed the new views, the agricultural industry is accepting them more (officialdom) or less (young farmers' league) reluctantly and the pesticides industry grumbles.

The newness, in my opinion, is in the rational approach to environment and its protection. To distinguish this approach from older attempts, which were far more emotionally loaden, the new approach is called the 'new environmentalism'. Rationality is imperative because the Dutch government explicitly wants to maintain the agricultural productivity and export volume of the Netherlands. A country such as Sweden preceded in environmental concerns and other countries may follow, but there is a difference. Sweden, though a great exporter of forest products, is not a typical exporter of agricultural commodities. The new environmentalism has all possibilities to become effective, as it is supported by a large, or at least a vociferous, segment of the Dutch population. If effectiveness is a criterion, we may speak of a drastic change in viewpoint, even a change of paradigm. As an arbitrary date I chose 1990, the year of the crucial policy papers.

At this turning point, crop protection has taken the lead, but in medicine there are changes too. Excessive medicare costs led the Dutch government to emphasize preventive medicine again. New schools and curricula have been set up in preventive medicine. At the same time, the public attitude towards 'official' medicine is changing. Clients become more critical, ask for 'alternative' treatments, and become more health conscious. Health food and physical exercise are popular. Ill youngsters consulting their physician may refuse chemotherapy and choose to 'sit it out'. In human health care the change in attitudes or in policy is not so drastic as in crop protection but it goes on.

Resuming two centuries of crop protection science and one century of the Netherlands Society of Plant Pathology, three typical turning points in general outlook became apparent, with such deep implications for plant protection science that I see them as paradigm changes indeed: 1890 definitively brought the primate of pathogenesis, 1940 brought the treacherous safety of chemotherapy, and 1990 the new environmentalism. Though the paradigm shifts did not falsify the old truths, they placed them in a radically different perspective, changing the opinions and actions of large segments of the Dutch population. These changes will give crop protection research new inpulses to study the ecology and epidemiology of pests, diseases and weeds and, hopefully, to strengthen integrated crop protection by a variety of new control measures (De Ponti, 1990).

3 Intermezzo

For long, plant pathology has been the science of the visible. The naked eye was the major instrument of phytopathology in the sense of 'observe what you see'. Such were the teachings of the lady professors, the visionary Johanna Westerdijk (1883-1961) and her meticulous successor Louise C.P. Kerling (Ten Houten, 1961; Oort and Ten Houten, 1970). Where the art of experimentation gained in importance I added 'think with your hands'.

As a matter of course, plant pathology at large took advantage of all new scientific developments and tried to transform these into new plant protection opportunities. The chemotherapeutant episode roughly coincided with the upsurge and development of biochemistry. At the incipient stage, a newly appointed professor of biochemistry suggested to 'tell me your problem and I will solve it within two years'. What biochemistry actually did was to provide the crop protection sciences with a wealth of knowledge, leading to deep understanding of pathogenesis, but not with solutions of actual crop protection problems. Most of the chemotherapeutants were found by the hit-or-miss method. Biochemistry has contributed to the understanding of their mode of action and to the modification of bioactive molecules. The understanding of tubulin synthesis was an elementary contribution to cell biology (Davidse and Flach, 1977). Certainly, biochemistry has increased the plant pathologist's awareness of things invisible to the eye, naked or armed with light or electron microscopes.

The narrow path of the visible is bordered by large areas of the invisible though not impenetrable. Two trails are being hewn, one exploring the molecular scene and another reconnoitring the area of agro-ecology. Both take simple phytopathological phenomena as a starting point, such as the appearance and explosion of a new pathogen or pathogenic strain, but develop fundamental views in close touch with more generalistic sciences such as distribution ecology (Van den Bosch, 1990; Zawolek and Zadoks, 1989) or molecular biology (Davidse and Flach, 1977; De Wit and Oliver, 1989). Both directions of research, so fundamental and different that two Chairs of Phytopathology were deemed necessary at the Wageningen Agricultural University, primarily intend to deepen the understanding of crop protection phenomena, but they also want to contribute to the immediate needs of crop protection in the new-environmentalist episode. With great foresight, Oort (1903-1987) stimulated developments in both directions already more than thirty years ago (Kerling and Ten Houten, 1969).

At the molecular level the present aim is to produce simple molecular constructs which can be inserted into any plant genome to protect the plants against a chosen stress agent. Several achievements are on record but, especially in the Netherlands, the general public is so concerned about undesirable side-effects of transgenesis that progress at field level is slow. This public cautiousness has to be accepted, in part as a heritage of the chemotherapeutant episode when many undesirable side-effects of pesticides were produced.

At systems level, the now classical quantitative epidemiology (Van der Plank, 1963) is developing into a broader approach including various aspects of disease and pest management (Frinking and Scholte, 1983; Rabbinge et al., 1989; Savary, 1986, 1991; Schouten, 1991). Aerobiology, systems analysis, dynamic simulation, numerical and analytical mathematics, optimalization theory and expert systems are the tools of this new trade, of which the computerized disease and pest control system for wheat named EPIPRE (Zadoks, 1989c) was but a forerunner. The divorce of crop husbandry and crop protection, which became marked during the chemotherapeutant episode, will be undone by the systems approach but *ipse quo* the necessary validation and verification of models becomes difficult though not impossible (Daamen, 1990; Dik, 1990; Van der Werf, 1988).

New contributions to the crop protection sciences came from the Phytopathological Laboratory 'Willie Commelin Scholten' at Baarn, unfortunately now being disbanded, with detailed studies on *Botrytis* under the aegis of Verhoeff (1965; Leone, 1990), antagonism in the rhizosphere under the guidance of Schippers (Schippers et al., 1987; Bakker et al., 1990) and the intricacies of the phyllosphere under the supervision of Fokkema (Fokkema, 1971; Dik, 1990). During the 'chemotherapeutant episode', Ten Houten with his characteristic verve created the Research Institute of Plant Protection (IPO) at Wageningen (De Wilde, 1975), an institute now fully geared to the next episode.

We enter the new-environmentalist episode with deepened understanding and powerful instruments. The Dutch environmental movement, nearly silenced by its recent successes, arrived at a point where it has to reconsider its outlook on science and society and its strategy for the future (Cramer, 1989). The crux of the matter will be to ask the right questions. A series of new questions generated by a new view on reality marks the change of paradigm. The change is dated 1990, when the meritorious 'Multi-Year Crop Protection Plan' was offered to the public.

4 Plant protection in the Netherlands beyond 1990

The 'new environmentalism' is characterized by a highly rationalistic approach. A flurry of policy reports (Table 3) led to a careful stock taking of Dutch agriculture, with conscientious weighing of possibilities and constraints, balancing costs and benefits. The effort of scores of people did bring forth the 'Multi-Year Crop Protection Plan' (MJPG) of 1990 with its massive body of annexes arranged per production sector, and its recommendations for research (De Ponti, 1990).

The following is the author's own interpretation of the MJPG and its implications for the new environmentalist episode.

4.1 Stock taking

The Netherlands took stock of their plant protection problems in 1990. The result is decidedly unpleasant. The situation in the Netherlands is peculiar because of (1) its high population density, (2) its great diversity of crops, (3) its high cropping intensity, and (4) its intensive usage of pesticides.

Table 3. Selected policy papers and memoranda relevant to the 1990 change of paradigm in crop protection.

1974	Commissie Onderzoek Alternatieve Landbouwmethoden. Alternatieve landbouw. Inventarisatie, evaluatie en aanbevelingen voor onderzoek. Wageningen, Pudoc. 159 pp.
1977	Commissie Onderzoek Alternatieve Landbouwmethoden. Alternatieve landbouwmethoden. Inventarisatie, evaluatie en aanbevelingen voor onderzoek. Commissie Onderzoek Biologische Landbouwmethoden. Wageningen, Pudoc. 398 pp.
1984	W.J. van der Weijden, H. van der Wal, H.J. de Graaf, N.A. van Brussel, W.J. ter Keurs, Bouwstenen voor een geïntegreerde landbouw. Den Haag, Staatsuitgeverij. 196 pp.
1984	Gewasbescherming in Nederland. Memorandum. Handelingen Tweede Kamer der Staten-Generaal.
1989	Zorgen voor morgen, Nationale Milieuverkenning 1985-2010. Alphen aan de Rijn, Samson. 456 pp.
1989	Nationaal Milieubeleidsplan. Kiezen of verliezen. Den Haag, Staatsdrukkerij en Uitgeverij. 258 pp.
1989	Natuurbeleidsplan. Beleidsvoornemen. Den Haag, Ministerie van Landbouw, Natuurbeheer en Visserij, 179 pp.
1989	Structuurnota Landbouw. Beleidsvoornemen. Den Haag, Ministerie van Landbouw, Natuurbeheer en Visserij, 139 pp.
1989	Om schone zakelijkheid. Perspectieven voor de agrarische sector in Nederland. Den Haag, Landbouwschap. 285 pp.
1990	Integraal Milieu Actieplan voor de Land- en Tuinbouw. Den Haag, Landbouwschap. 150 pp.
1990	Voortgansrapportage. Integraal Milieu Actieplan voor de Land- en Tuinbouw. Den Haag, Landbouwschap. 161 pp.
1990	MJPG. Meerjarenplan Gewasbescherming. Beleidsvoornemen. Den Haag, Ministerie van Landbouw, Natuurbeheer en Visserij, 137 + 133 pp.

Table 4. Estimated average annual use of pesticides in the Netherlands over the years 1984-1988, expressed in kg of active ingredient. Source MJPG-1990.

Sector	Area in 1000 ha	Use per year in 10^6 kg	Use in kg ha^{-1} $year^{-1}$
Arable husbandry	751	14.2	19
Field legumes	45.2	1.3	28
Flower bulbs	17.9	2.1	120
Arboriculture	6.6	0.5	76
Fruit growing	23.4	0.47	20
Animal husbandry	1150	0.72	0.7
Public areas	700	0.12	> 0.2
Flower production	6.5	0.63	96
Covered legumes	4.4	0.47	106
Edible mushrooms	0.09	0.01	112
Totals (approx.)	2000	21	10

Due to the high population density land is a scarce resource, compelling growers to intensify production. Though less than 5 per cent of the population is engaged in agriculture, up to 12 % is closely connected with agriculture in supply, production and processing. Together, they make the Netherlands into the world's second exporter (in value) of agricultural commodities, closely behind the USA. Rural and non-rural people live on each others' lips, so that immediate and long-term interactions between these two segments of the Dutch population occur. Quality of the product, the production process, and the production environment are points of confrontation.

Apart from the normal arable and horticultural crops of the temperate atlantic zone there is a large array of ornamentals and specialties, in the open or under cover, about 600 different crops in total. As many products are grown for export, which requires perfect presentation, or for demanding customers, again caring for good appearance, plant protection is intensive (Table 4). The Dutch pesticides use of, on average, 20 kg of active ingredients per hectare (if pastures are excluded), sets a sad world record.

The Dutch public no longer accepts the situation. Administrative decisions, abiding parliamentary confirmation, have set the strategy and the targets.

4.2 Strategy and targets

The strategy is given in three points:

(*i*) Reduction of the dependence on chemical pesticides.
(*ii*) Reduction of the use of chemical pesticides.
(*iii*) Reduction of the emissions of chemical pesticides to the environment.

Objective (*i*) can be obtained by a variety of approaches, among which figure the preferential use of (and, if necessary, the future breeding for) resistant varieties, enlargement of the rotational cycle, biological control of pests, diseases and weeds, and cultural measures. The point represents a long to medium term approach. Objective (*ii*) is reinforced by point (*i*) in the long run, but it can be implemented sooner. Need-based treatments will replace schedule treatment where feasible. Regulatory action will reduce various uses of pesticides, as e.g. in drinking water source areas. Objective (*iii*), reduction of the emission of chemical pesticides (as opposed to biological pesticides) to non-target compartments of the environment (air, soil, and water), will be reduced by a variety of measures as, for example, restriction of aerial applications, improved formulation of pesticides preventing evaporation, improved design of machinery leading to e.g. recuperation and recycling of the spray material which does not reach the target, and construction of closed circuits in covered crops. New research will be needed to implement the MJPG strategy (De Ponti, 1990).

The MJPG-1990 sets the targets, following the 'Agricultural Structure Memorandum' (SNL) of 1989. In the year 2000, the reduction in the total use of pesticides should be at least 50%, the reference value being the average use over the years 1984/89 (about 20 million kg active ingredient applied on 2 million hectares, pastures included) and the reduction in the use of soil disinfectants at least 80 per cent relative to the use in 1985. The long list of registered pesticides is being revised so that many older pesticides, which do not comply with the newly set environmental criteria, have been or will be withdrawn from the list. Plans have been made for each of 10 production sectors to attain these targets and, in actual fact, implementation has begun before any parliamentary decision was made (a typically Dutch approach). The avenues taken for implementation differ according to the type of crop, a major distinction being that between open and covered crops.

The covered crops, among which vegetables, flowers and other ornamentals, and mushrooms, produce much of the agricultural income of the Netherlands. A majority of these are already grown under high-tech conditions, such as cultivation without soil. Improved production technology reduces the risk of pests and disease, allows safer application and lower dosages of pesticides, and – with added investment – reduces emission of pesticides to very low levels indeed. Hygiene and prevention of infection/infestation are to be improved. As more attention is given recently to breeding for resistance, even in ornamentals and flowers, the future dependence on pesticides will be reduced.

The open crops, arable crops, vegetables, fruits, flower bulbs and other ornamentals, are less amenable to such high-tech solutions. The still experimental Integrated Farm (Zadoks, 1989b) of today provides guidance in arable farming and stands as the model for the Current Farm of 2000. Today's Current Farm will be a museum piece in 10 years time. A major problem is the absence of a generally acceptable 'fourth crop', to be rotated with the two cash crops potatoes and sugar-beet and the break crop wheat. In arable crops, resistance has always been in active pursuit and little improvement can be expected in the short run. Only in potatoes, the most polluting field crop, there is scope for rapid change if the highly favoured cv Bintje (since 1906), which requires so much treatment against *Phytophthora infestans*, will be replaced by more resistant varieties of about equal consumer value and at least equal production.

Pest and disease warning systems exist already for a long time, but since they are not always used rapid change is possible. Reduction of emission by means of new and better machinery, where necessary enforced by new regulations, will certainly lead to great improvements. Similarly, in fruit, vegetable, ornamental, and flower bulb growing improvements are forseeable and experiments for 'integrated production' are being started.

4.3 Cultural methods

In open crops, the major issue is rotation, supplemented by choice of variety, choice of planting date, moderation of fertilizer usage, and adjustment of harvesting techniques and handling of crop residues. The optimization of nitrogen applications, as fertilizer and/or manure, has agronomic, environmental and crop protection aspects (Daamen, 1990). In covered crops, rotation problems were increasingly circumvented by cultivation without soil, now to be supplemented by 'closed cultivation'. Closed cultivation will consist of technologies and procedures to avoid the immission of harmful agents and to prevent the emission of pesticides and surplus nutrients.

4.4 Genetics

Vertical resistance can be stable (Eenink, 1976), especially when it is supported by cultural methods such as a wide crop rotation or a ban to grow the crop, but more often it is unstable because pests and pathogens adapt. Gene management can contribute to the durability of vertical resistance (Zadoks and Schein, 1979) but the methods advocated have not been accepted for one reason or another.

Gene deployment by means of a regulated regional use of certain resistance genes is, for example, at variance with European Community regulations. In cereals, varietal mixtures have demonstrated their production and plant protection value over and over again; experiments on the protective effect of varietal mixtures against yellow rust (*Puccinia striiformis*) have proved the point from 1958 (Zadoks, 1958) until 1988 (Luo Yong, 1990; Van den Bosch, 1990), but the results were never accepted by breeders, farmers and grain merchants.

Partial resistance was strongly advocated by Parlevliet (1979) and methods to breed for partial resistance were investigated (Broers and Jacobs, 1989). Acceptance of partial resistance will be easier if a good pest and disease warning system is available in case of need (Zadoks, 1975) or when partial resistance enhances biological control.

During the chemotherapeutant episode the interest in breeding for resistance slacked at least with respect to some 'recalcitrant' pests and diseases. Resistance was about the last item to be selected for in fruits and ornamentals, with one exception. De Wilde's (1965) message to breed for resistance against insect pests has been picked up by the Institute for Horticultural Plant Breeding (IVT, now part of CPO, Centre for Plant Breeding Research, Wageningen). It seems that in the new spirit breeding for resistance to biotic and abiotic stresses will be boosted.

4.5 Biotechnology and genetic engineering

The promises of biotechnology and genetic engineering have aroused special interest, first of course among scientists, second among investors, and third among those who view any scientific innovation with a critical or even suspicious eye. The new technologies can speed up some operations, such as multiplication of new selections *in vitro*. Several private, semi-public and public institutions in the Netherlands are presently involved.

'Gene constructs' are produced for insertion in a plant genome to make the plant resistant against viruses and insects, in the expectation that the plant's agronomic and consumer values remain unchanged except for the desired resistance. Work is in progress on other constructs which will protect plants against bacteria, fungi or nematodes.

The present situation in the Netherlands is such that resistance to virus can easily be inserted into a variety of plants. Constructs for resistance to nematodes are in an incipient stage of development. Constructs for resistance to fungi can probably be made in the near future by using the patented method of De Wit (1990).

For the implementation of the Multi-Year Crop Protection Plan, 'early detection' of organisms in combination with refined field sampling strategies is of crucial importance (Schomaker and Been, 1989). Immunoassays using polyclonal and monoclonal antibodies (Schots et al., 1990), protein variation studies (Bakker, 1987) and DNA probes have been developed. The same techniques allow to study the molecular epidemiology of pests and pathogens (potato cyst nematodes: Bakker, 1987; *Phytophthora infestans*: in preparation).

The major barrier is neither technology nor money but public concern about undesirable side effects. All experiments are carefully screened by a Governmental Biosafety Committee (VCOGEM, 1990), which adheres to a conservative, safety-first policy. So far, no genetically manipulated cultivars have been registered for commercialization in the Netherlands.

Plant protection risks from genetically engineered varieties may seem negligible but history contains some warnings. The famous case of Texas male sterility (TMS) in maize, a prestigious result of what today might have been called biotechnology, is not yet forgotten; the mitochondrial TMS genes conditioned specific susceptibility to an unimportant race of an unimportant pathogen, and US agriculture suffered a 10 billion dollar loss in 1970 (Anonymous, 1972).

Such things might happen again, the more easily when the constructs contain fragments of chromosomes in stead of 'pure' genes only. Environmental risks, such as transgenes pervading and eventually disturbing the native flora, are being considered. The risk of break-down of resistance is as real as ever. Insertion of *Bacillus thuringiensis* (BT) genes in plants for insect resistance has already led to BT-resistance in insects. The risk of substituting one evil by another one exists. Should we ban all herbicides in maize cultivation and make it unprofitable, or use genetically engineered glyphosate-resistant varieties so that the environmentally less damaging glyphosate can replace the more harmful atrazin?

4.6 Biological methods

Crop protectionists study species at different food levels in the ecosystem. The sentence 'parasite eats bug eats plant' characterizes the tritrophic pathosystem, the subject of most studies in biological control. These begin with a loose remark by the Dutchman J. Goedaerdt (1620-1668), a first thorough study by A. Van Leeuwenhoek (letter to the Royal Society 26 October 1700), to be continued to these very days (Van Lenteren, 1985). In the new-environmentalist episode such studies obtain more weight in entomology (Noldus, 1989), acarology (Dicke, 1988), and phytopathology (Hofman, 1988; Hijwegen 1988).

As to baculoviruses used in biocontrol of caterpillars, the modern toolkit of biotechnology permits genetic modification to speed up their killing effect and to cripple their survival in nature, and allows large-scale production in fermentors using insect cell cultures (Kool et al., 1990).

Biological control is relatively cheap to develop (Van Lenteren, 1985) and causes a minimum of pollution. In the Netherlands, where the links between fundamental research, applied research and pratice are close, biological control of insect and mite pests in greenhouses has become a success story (Van Lenteren and Woets, 1988), and in apple orchards it makes good progress especially due to the reintroduction of predatory mites. In field crops, however, we are far off the mark except, maybe, for the commercial application of sterile males to control the onion fly, *Hylemia antiqua*.

Choices become difficult when it is found that the application of deltamethrin and tillage are about equally damaging to the webbing spiders which keep aphids in check (Everts, 1990). Enhancement of natural control of aphid pests in field crops by carabids and staphylinids, by syrphids and coccinellids, by spiders and entomophagous fungi seems feasible. Nevertheless, the problem is 'recalcitrant' since there is a lack of knowledge on cause and effect in the Netherlands. Is 'habitat management', with for example newly made woods and roughages as insect breeding sites, a realistic proposition now that so many farms have to close down due to recent changes in Common Market price policies?

Biological control of weeds by means of their fungal diseases is, again, a recalcitrant problem. In one case, control of the exotic *Prunus serotina* by means of the native fungus *Chondrostereum purpureum*, it was shown to be feasible and an environmental impact or risk assessment was made (De Jong, 1988). A mycofungicide will be on sale soon.

Biological control of some beetle pests by means of nematodes (Simons, 1981), used rather as living injection needles for the toxin producing bacteria they transmit, is commercial in the Netherlands. Exploiting the killing capacity of the bacterial toxins by means of biotechnology is on its way.

4.7 Chemical control

Though chemical industry produces few new active ingredients at the moment, and economic prospects for the pesticides industry are not glorious, we cannot renounce agrochemicals, whether pesticides or resistance enhancing substances. In my opinion, chemicals will be needed in the future to improve resistance, to fill gaps where no alternatives avail, possibly to protect consumers against mycotoxins (far more dangerous than any fungicide), and to correct excesses (as a 'fire brigade' function).

Whereas first generation pesticides were generally of the broad spectrum, persistent type to be applied in kilograms of active ingredient per hectare, we are presently welcoming a third generation, applicable in grams per hectare. The active ingredients consist of biologically highly active molecules, usually with a broad but clearly defined spectrum of activity. A useful criterion might be the (marginal) pesticide efficiency, expressed as the extra production of dry matter in kg ha^{-1} divided by the extra amount of active ingredient in kg ha^{-1}. An approximative figure for aphid control in wheat by deltamethrin might be 1000 kg of produce saved by 5 grams of active ingredient, or a pesticide efficiency of 200 000.

Private industry works hard to develop and refine seed coating techniques. Pesticide efficiency will be boosted by a factor ten to hundred in comparison to classical, broadcast field treatment (Breukink et al., 1989). Useful pesticides, which have to be banned from classical field uses, could probably be maintained for these special treatments.

The present-day, indiscriminate rejection of pesticides by the public and by many governmental officers should be refuted. A more grown-up and educated attitude towards pesticides is needed in the future to strike the right balance between the economics and the environment of agriculture (Anonymous, 1990).

4.8 Regulatory activity

The regulatory activities of the Dutch government but also of the agribusiness itself will increase considerably. Many pesticides will be banned. Others will be registered for limited application, e.g., not in drinking water source areas, or for seed treatment only. Other limitations will deal with reduction of emission, e.g., by not spraying a 5-m-wide strip along the field borders. Pesticides will be taxed and the revenues used to develop and promote new pesticide-free control methods. Application of crop protection chemicals on prescription only is under consideration (and *de facto* already in use for streptomycin against fire blight), especially for soil disinfection by nematicides.

The processing industry will impose its own regulation. Food retailers will not only ask for a product free of pesticide residues but they will also require guarantees for pesticide-poor production methods. Today's supermarkets offer the public a choice. One may extrapolate that today's choice by the affluent customers will be tomorrow's choice by the general public.

Growers will want increased safety from pests and diseases by means of clean seed and planting stock, produced in fields free from diseases, even in environments free from diseases transmitted by planting material. In addition, when using their own or hired land, growers will want freedom from soil-borne pests and diseases, to be guaranteed at far lower detection thresholds than today (Schomaker and Been, 1989). In many cases, as with potato cyst nematodes, the tests will be species- and even biotype-specific (Bakker, 1987; Janssen, 1990; Schots et al., 1990).

These requirements open a new field of research, low intensity disease and pest detection. Biotechnology offers good prospects for the development of diagnostics to identify very low levels of infection/infestation by means of monoclonal antibodies and/or nucleic acid probes. The 1990 prospects are such that not the probes but the sampling techniques will become the limiting factor.

4.9 Integrated pest management and integrated agriculture

Integrated Pest Management (IPM) is the buzz word, but the art of integration is still underdeveloped. The new approach is less straightforward than the recent production and protection methods, less robust also, more vulnerable to disturbance. They require an incredible amount of fine tuning, for which most of the research still has to be done. Developments are sought in three directions, (1) early detection, (2) sampling, and (3) management of pests and diseases.

Fast identification of a pest or disease will be needed in a small and preferably unpurified sample, a 'litmus test' yielding green if the pest is absent and red if present. Biotechnology comes to the aid and several diagnostics are ready for marketing. In the Netherlands, a test for potato spindle tuber viroid was developed at an early date (Vos, 1987). Only one potato cyst nematode is needed to tell its species, *Globodera pallida* or *G. rostochiensis* (De Boer et al., 1991).

Management of pests and diseases taking into account sliding damage thresholds, handling all the available information, will become a problem in itself. Work is in progress to establish new action thresholds in greenhouses and orchards, which will drastically reduce the number of treatments per season against pests. Computerized systems such as EPIPRE (Zadoks, 1989c), developed in the Netherlands and also used in other countries, may be part of the solution. Expert systems, not yet abundant in the Netherlands, may contribute.

The new farming is expected to use fewer external inputs than current farming, but it will be far more knowledge-intensive. Crop protection is and will be an indispensable element of agricultural production. A close connection exists between the paradigm change dated at 1940 and the onset of the 'green revolution'. Similarly, the paradigm change of 1990 is symptomatic for changes in agriculture at large, where the trend is toward 'durable', 'integrated' (Europe) or 'sustainable' (USA) agriculture (Zadoks, 1990).

5 Epilogue

The foregoing highlighted some remarkable features of plant protection in the Netherlands as it developed during the century spanned by the world's oldest phytopathological society. The Society took an active part in this development, for example by organizing annual meetings and timely symposia on upcoming issues, and it will no doubt continue to do so. Several persons, usually active members of the Society, and their contributions to the science and practice of plant protection have been mentioned. The Society has been one of the platforms for discussion. The journal 'Gewasbescherming' (= Crop Protection), published in Dutch, has shown to be a good medium for communication at the national level.

The Society continuously promotes the science of plant protection by organizing national and international meetings and by publishing the Netherlands Journal of Plant Pathology (NJPP), which having started as 'Tijdschrift over Plantenziekten' anglicized its name. It is the world's second oldest plant protection journal. As a general journal on plant pathology it is small in volume but among its 'congeners' it ranks second to Phytopathology in impact factor (Fuchs, 1990), a worthy medium for international communication. The Society took the initiative to charter the 'European Federation of Plant Pathology' in 1990.

The membership of the Society (some 700 in the Netherlands) comprises nearly all people engaged in plant protection, college trained extension workers, university trained researchers, self- made merchants, advanced growers, and students in plant protection. They all contribute enthousiastically to plant protection, its development and its implementation, and new ideas are born and tested at any level of training or sophistication. In the complex world of today the Society is no longer the only grouping of people in the Netherlands interested in plant protection, but it will continue to represent the profession.

Agriculture in the Netherlands is extremely productive and intricate. The country faces plant protection problems which are among the most difficult in the world. The profession is ready to face the consequences of the third change in paradigm during the second century of the Netherlands Society of Plant Pathology, a system of plant protection with an improved balance of economic and environmental values.

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