


Review

Review of the Genesis of Plant Pathology and Its Relation to the Phytiatry as a Necessary Element in the Sustainable Development of Agronomy

José Del Moral de la Vega and Jerónimo Del Moral Martínez * 

Grupo Investigación Calidad y Microbiología de los Alimentos (AGAO17), Instituto Universitario de Investigación de Recursos Agrarios (INURA), 06071 Badajoz, Spain

* Correspondence: jeronimodelmoral@yahoo.es

Abstract: The origin of plant pathology as a scientific discipline can be traced back to botany in the 18th century. In the following century, with the contributions of De Bary and Kühn, this discipline was able to identify the causes of diseases, learn about their development, and propose therapeutic measures, which is why these two researchers are considered to be the fathers of plant pathology. This account of its genesis is the one that appears in the histories currently published about it, but the discoveries of other authors who participated in its origin, whose work had not been taken into account, modify their knowledge. Among these authors are De Candolle and Blanco Fernández. The establishment of plant pathology, with a generalist, multidisciplinary, and integrative sense, as an academic discipline in the nineteenth century, disappeared together with some of the historical figures responsible for it, when other disciplines were born from it, and yet it is coincident with the current concept of phytiatry of the twenty-first century. The power to re-establish the characters and facts responsible for this historical moment allows us to review the current concept of phytiatry so that it fits with the greatest possible precision as a necessary tool for the sustainable development of agronomy as well as food security and is established as an indispensable part of a single global health concept.

Keywords: plant health; phytopathology; plant diseases; plant medicine; sustainable crop production; De Candolle; Blanco Fernández



Citation: Del Moral de la Vega, J.; Del Moral Martínez, J. Review of the Genesis of Plant Pathology and Its Relation to the Phytiatry as a Necessary Element in the Sustainable Development of Agronomy.

Agronomy **2023**, *13*, 1285. <https://doi.org/10.3390/agronomy13051285>

Academic Editors: Susana Pascual, Gloria Nombela and Francisco J. Beitia

Received: 23 March 2023

Revised: 25 April 2023

Accepted: 27 April 2023

Published: 29 April 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Plant diseases, like those of other living beings, are physiological or morphological alterations that appear throughout their lives; diseases are exalted when plants are cultivated, so that the beginning of the history of plant diseases goes hand in hand with the beginning of agriculture and, consequently, with the prehistory of mankind. From then until the modern age, it developed mainly through the observations of numerous authors, including, in the ancient age, the Greek Theophrastus; in the Middle Ages, Ibn al-‘Awwām “the Sevillean”; and, in the modern age, Alonso de Herrera.

One of the most important consequences of the scientific, agricultural, and industrial revolutions was an exaggerated demand for food due to the increase in population, which was provided by the intensification of cultivation and trade in plants between the New and Old Worlds, leading to the emergence of serious crop diseases.

At the end of the 18th century, the botanists who approached the study of these diseases were imbued with the Linnaean spirit that was taking hold in the natural sciences, and their studies, based on observation, were oriented toward the classification of the diseases by the symptoms shown of the affected plants. In 1728, Duhamel distributed sclerotia of *Rhizoctonia violacea* in a soil free of them, planted various crops in this soil, and found that some of them died [1] (p. 17). From then on, knowledge about plant diseases was no longer based solely on observation but began to use experimentation.

One of the diseases that most limited wheat cultivation in the 18th century was the disease known by farmers as “bunt of wheat” because of the black color of the wheat grains. In 1807, Prevost [2] demonstrated that the fungus *Tilletia foetida* was the cause of the disease, challenging the then prevailing idea that the molds appearing on diseased plants were the result of the disease. Following Prevost’s experiments (1807), which showed that the cause of a wheat disease was a microscopic plant classified as cryptogam (without flowers), De Candolle published in 1832 [3], within the field of botany, a classification of diseases according to the biotic or abiotic causes that produced them. The classification elaborated by De Candolle was significantly modified by Dr. Blanco Fernández, which he called plant pathology (1845–1851), studies that he taught in a chair created for this purpose in Madrid (1838) [4] (pp. 578–579) [5] (pp. 95–96).

With the knowledge provided by botany and the help of the laboratory, especially the microscope and field experiments, several researchers, notably Berkeley (1846) [6], Tulasne (1853) [7], De Bary (1853) [8], and Kühn (1858) [9], identified numerous disease-causing cryptogams [10] (p. 41), putting an end to the idea that the molds appearing on diseased plants were the result of disease.

The publications by De Bary (1853) [8] and Kühn (1858) [9] on their experiments opened an extraordinary field of study on plant diseases, which is why these authors appear as the founders of plant pathology. Shortly afterward, in a publication by Hartig (1874) [11], he determined that only diseases produced by phanerogams and cryptogams should be considered as diseases, determining that damage produced by insects would be of interest to agricultural entomology. From then on, the study of plant diseases fell into three areas of knowledge: plant pathology or phytopathology, agricultural entomology, and weed science. Although there is no higher structure to harmonize them, these three disciplines are still in use today, along with many other specialties that have emerged from them, such as acarology, bacteriology, physiopathology, nematology, virology, and so on.

This is the sequence of events that, since the 18th century, has taken place in the genesis of plant pathology, although not all the events that have occurred are mentioned in the history of this discipline, reasons that justify a revision of the genesis of plant pathology in which all the events currently known are integrated.

At the end of the 20th century, the decrease in food production that was being observed because of plant diseases was enormous, with losses that, with respect to the eight most significant crops in the world, were estimated to generate a decrease in agricultural production of between 40 and 45% [12] (p. 317). This prompted many authorities and institutions to consider how to proceed, concluding that in order to avoid them and design effective and environmentally friendly procedures, multidisciplinary integration in the manner of human and veterinary medicine must be generated, a proposal that began to be put into practice at the beginning of this century in several universities [13–15]. The genesis of this new profession, “plant medicine”, based on the historical development of the genesis of plant pathology, is not well known, and the semantics that define it cause confusion with other areas of knowledge in the health sciences (many people, given this name, believe that this discipline refers to plants used in human or animal health), problems that need to be solved for a correct transfer of knowledge, both in the scientific field and in the technological and productive sectors of agriculture.

Establishing a correct structuring of the genesis of plant pathology and its relationship with the genesis of phytiatry (the name given in some countries to “plant health medicine” or “plant medicine” in others) makes it possible to avoid the errors that it triggers and has already triggered confusion regarding an adequate consolidation of the definition of the area of knowledge as has been found in other related areas [16].

This article is the result of a review of the knowledge that has so far been available on the genesis of plant pathology, as well as its relationship with phytiatry. In order to present the work carried out, this article is structured, in addition to this introduction, into six further sections. Section 2 lists the main works on plant diseases published in botanical works in the 18th century. Section 3 describes the scientific knowledge on plant

health that existed in the first part of the 19th century, which led to plant pathology being considered a discipline. Section 4 describes the experiments and studies of De Bary and Kühn, which opened an extraordinary field of study and initiated the so-called “experimental plant pathology”. Section 5 describes the division of pathology into three disciplines: pathology, agricultural entomology, and weed science. Section 6 sets out the reasons that are considered to have motivated the creation of the phytiatry and its structure. Section 7 is a consideration of what this work has achieved.

2. The First Chapters on Plant Diseases Appeared in the 18th Century

The discovery of the microscope at the beginning of the 17th century made it possible to study fungi, eukaryotic organisms responsible for many plant diseases. Since Hooke published his studies of the common bread mold using the microscope in 1665 [17] (p. 269), there have been numerous publications describing different species of mycomycetes, but in 1709, Noël Chome took an extraordinary step forward by stating that different crops had their own specific molds. A few years later, in 1728, Duhamel discovered that what farmers called “saffron wine sickness”, by the vinous color of the bulbs of the diseased plants, was a cryptogam—now called *Helicobasidium purpureum*—that was transmitted from one bulb to another. In 1762, he admitted that some insect species caused plant diseases [18] (p. 232), and in 1767, the Italians Fontana and Tozzetti described different morphological structures of rusts in various species.

In 1735, Linnaeus published his work “Systema naturæ”, and it had an extraordinary influence on the classification of living beings and on the progress of knowledge in different fields of biology. Regarding fungi, the Dane Johann Christian Fabricius published in 1774 a classification system of pathogenic fungi in which they were arranged by classes, genera, and species [19] (pp. 2–3).

The advances made in botany in the 18th century were also reflected in the knowledge of plant diseases, about which sections appeared in botanical treatises.

In Palau y Verdëra’s study of the publications of Linnaeus and Tournefort, he discovered that plant diseases were viewed in the works of these authors as a result of the decrepitude that all living beings experience throughout their lives, or because they develop in an adverse environment, but without them seeing the need to classify them, limiting themselves to describing the symptoms manifested by diseased plants: “All living things are subject to many diseases, and so are the plants, which really live; but they do not stop their very old age is a disease. Because the soil where they are raised is bad, they sometimes suffer from various ailments” [20] (p. 202).

The first study we have found aimed at classifying plant abnormalities is to be found in a publication by Adanson, whose classification procedure is based on external symptoms—semiology: “The most common plant diseases can be divided into external and internal causes. There are 23 different types, of which 15 are external and 8 internal, namely: 1. burn (transparency by destruction of the parenchyma). 2. frost (white powdering). 3. Rust [...] 23. Sudden death” [21] (p. 42).

Based on human nosology, Von Plenck developed a classification, for which he created nine classes with numerous subclasses: “I. External lesions, II. Weaknesses, IV. Cachexia, V. Putrefaction, VI. Excrescences, VII. Grossness, VIII. Sterility. IX. Animals hostile to plants: 1. insects, 2. worms, 3. mammals, IV. birds” [22] (pp. 164–168).

Filippo Re suspected that plant pathology did not have the development it should have because of an inadequate procedure of disease classification: “A strong suspicion has arisen in me that one of the reasons why plant pathology is still in its infancy, and progresses so slowly, is the deep-rooted idea that it should be studied in a system exactly analogous to that of animals” [22] (p. 22). To obviate this problem, he made another proposal: “All plant diseases, so far as we know, are divided into five classes: Constant sthenic diseases. Constant asthenic diseases. Diseases which may arise from the sthenic state or from the asthenic state. Lesions. Unspecified diseases” [23] (p. 29). Within these five classes, he placed 91 genera, which in

turn contained 70 species. All these categories correspond to the various symptoms that appear on diseased plants, regardless of the cause (cold, water, insect, spider, plant, etc.).

In 1828, Boitard published a botanical work “Manuel complete de Botanique” in which he included a section entitled “Phytotherosie” on plant diseases. It includes plant pathology and nosology, the former consisting of the classification published by Plenck and the latter by Re [24] (pp. 173–182).

Until then, all the proposed studies were aimed at organizing a body of knowledge on diseases, but because they were based on the symptomatology of the affected plants, some diseases were classified as identical but differed in their causes.

The increases in wheat production in the 18th century, as a result of the technical improvements introduced in agriculture, led to the appearance of diseases that significantly reduced harvests, one of which, which farmers called “caries or blight”, led to the total destruction of production in some seasons and the consequence of which was famine in those areas where it appeared. Studies carried out on this phenomenon in the second half of the 18th century by Tillet revealed that the disease was caused by a “contagious principle”: *“That the ordinary cause, the abundant source of rotten wheat is in the dust of corrupted wheat grains; that these grains, once infected, turn into black dust, and become the cause of corruption for others”* [25] (p. 143).

This discovery was continued by other authors, such as Tessier and Martínez Robles [26,27], who showed the results of their examinations of the structure of the diseased grains under the microscope: *“If examined under the microscope, after several hours of infusion in water, it offers nothing but a considerable cluster of semi-transparent globules, very distinct and tightly packed against each other”* [26] (p. 217).

Tessier’s observations on the decay or blight of wheat led him to consider that, although there were several edaphic and phytotechnical variables related to the disease, none seemed as influential as the contagious principle pointed out by Tillet: *“One can only suspect that there is a particular cause, which gives rise to decay in some individuals of wheat; for so far it is not known. It is quite certain that it is not the fogs, nor the various fertilizers, nor the nature of the soil: whatever it is, its effects are not as active as those of contagion”* [26] (p. 258).

The studies carried out on the appearance and extension of “caries” and the contents of diseased grains under the microscope had led to the intuition of the primary cause of the disease, a hypothesis that was confirmed by Prevost through experimental work. Prevost carried out numerous microscopic observations and laboratory experiments, which led him to suspect that the corpuscles he observed under the microscope were the source of the disease: *“When we observe the dried caries powder under the microscope, with a strong glass, we notice that it is composed of brown, almost black grains, fairly equal, and approximately spherical [. . .] The grains or globules that make up the caries powder are therefore the seeds (gems, gemmules or gongolas) of a microscopic plant, and this same plant is the cause of the grain disease”* [2] (pp. 2–5).

But to be sure that it was these corpuscles that caused the charcoal, Prevost carried out numerous experiments in the field and found that when he dispersed these particles from inside the grains on the wheat crop at certain phenological moments, from sowing to glean, he reproduced the disease. From the shape of the corpuscles that caused the disease, which resembled the “corpuscles” of rusts, Prevost deduced that they belonged to a cryptogamous species, although he did not specify their identity.

A few years after Prevost discovered that wheat decay was caused by a cryptogam, Martínez Robles published a booklet, the first we have reference to, devoted entirely to plant diseases, in which he included various cereal diseases: *“Dissertation on the diseases of wheat, barley, maize, rice and other cereals (1819)”* (“Disertación sobre las enfermedades del trigo, cebada, maiz, arroz, y otros cereales (1819)”) [24], in which he relied on the most renowned authors of the time, Banks, De Candolle, Filippo Re, Parmentier, Prevost, Tessier, and Tillet. He grouped the diseases considered into three categories, according to the atmospheric circumstances surrounding the plant, the soil where they were grown, and the “damaging” plants where they were grown. Among these he included numerous weeds, such as *Centaurea* sp., *Papaver* sp., *Avena* sp., etc., and among those produced by

cryptogams, he described rust, wheat and maize charcoal, ergot, and blight. Martínez Robles devoted the greatest attention to the latter, describing the symptoms shown by diseased plants, the morphology of the fungus that produces the disease, the epidemiology, and the conditions that favor it, as well as the recommended measures to avoid or reduce it [27] (pp. 40–59).

With the publications by Prevost and De Bary on the results of their experiments, it seemed to be sufficiently demonstrated that the cryptogams present on diseased plants were the cause of the diseases; this is why this theory, which based the origin of diseases on germs instead of attributing them to the environment, became known as the “germ theory”, but this theory was not accepted by all farmers and scientists at the time: *“The causes of disease are laid by farmers partly on defective fertilisation, partly on dryness of air and soil, partly on excessive moisture, partly on the alternation of both conditions; partly on bad, wet or badly ripened seeds, partly on all or many of these circumstances together”* [8] (p. 106).

This incredulity was expressed even by scientists of great prestige, such as the professor of plant physiology, Unger, who was Mendel’s teacher (Mendel’s discoveries are considered to have originated from hypotheses outlined by Unger): *“(Diseases) must be attributed to an inadequate soil mixture, to other random local conditions, and partly to deeper atmospheric powers, against which the weak and impotent plant life is little able to protect itself”* [28] (p. 3). However, the results of successive experiments eventually confirmed the germ theory. *“Accidental diseases are those which are produced instantaneously, either by the effect of some shock, or by atmospheric influences, or finally by the effect of the presence of certain harmful insects, or of certain plants, which live as true or false parasites, finding on the surface or under the surface of some plants, or in their interior, the suitable territory for their fixation”* [29] (p. 5).

3. Establishment of Plant Pathology as an Academic Discipline

The propositions that some authors had made regarding diseases caused by insects, together with the result of Prevost’s experiments, which attributed the appearance of caries in wheat plants to a cryptogam, were reasons that led to classifying them according to the causes that produced them, De Candolle being the first botanist to do so.

Before De Candolle’s publication of *“Physiologie végétale”* (1832) [3], the chapters on plant diseases in botanical publications were inspired by the ideas prevailing in human medicine. It is to De Candolle that we owe the rational basis of a treatise on plant diseases by considering them as alterations to the normal physiological state they should have, abnormalities produced either by the unfavorable conditions of the environment in which they vegetate or by the action of parasitic organisms that penetrate their tissues [30] (pp. 10–11). With these principles, De Candolle made a classification of diseases, while retaining the same name—nosology—that had previously been used by Filippo Re (1807 and 1817) [23,31]: *“The use (of pathology) in its etymology recalls the idea of suffering, may be appropriate for the morbid disorders of man and animals, almost all of which are mixed with pain; the second (nosology), which simply indicates the idea of disease without mixing the idea of pain, seems to me, following the example of M. Ré, preferable to admit it when dealing with plants”* [3] (p. 1061).

The reason for basing the classification of diseases on their etiology, which prompted De Candolle, rather than on the symptoms that characterize them, was explained by De Candolle as follows: *“The external symptom is therefore of little importance here, and it is to the efficient cause of the disease that the attention of the physiologist and the grower must be directed. The agents whose influence is exerted on plants can be classified in two series: 1° some are nothing other than the very agents which serve the life of plants, such as light, electricity, heat, water, air, soil. . . . 2° There are other agents which are not necessary for vegetation, but which affect plants so frequently that it is necessary to appreciate their action: they are, for example, the mechanical or chemical influences of raw materials on plants, of plants on each other, or of animals on plants”* [3] (pp. 1066–1677).

The etiological proposal made by De Candolle was significantly modified by Blanco Fernández (1809–1873) some years later [32].

During the two-year trip (1836–1838) Blanco Fernández made to numerous botanical and agronomical centers in various European countries, he visited De Candolle in Geneva, where he got to know his studies firsthand: *“Everything, everything, was at my disposal during my stay in a place so pleasant for me, and at the side of this immortal genius, so kind, whose virtues and science make him worthy of the name of Divine [. . .] in his house I found my father’s house, and in his kind family and dear friends who gathered there. I found many others who gave me thousands of attentions”* [4] (p. 566).

De Candolle’s systematization of plant diseases was modified by Blanco Fernández in a long chapter entitled “Plant Pathology” in his work *Botany* (1845–1846). The use of De Candolle’s criteria is justified by Blanco as follows: *“This method offers, in our humble opinion, a certain advantage, which is that of being able to know the cause which produces this or that ailment, in order to remedy it, or to preserve the plant from it, by avoiding its action. This is extremely useful to the farmer, and much simpler than not to worry about the external symptoms, since many of them, of the same kind, are produced by entirely different causes”* [33] (p. 78).

This work, corrected and enlarged, was published under the title of “Curso Completo de Botánica”, in the second volume of which he again develops the subject of plant pathology at length [34] (pp. 51–182).

Blanco Fernández follows De Candolle’s argumentative path, although he qualifies and modifies these postulates, modifications that reveal significant differences when examined:

- De Candolle reserves the name “pathology” for the morbid states of man or animals and assigns the name nosology to the study of plant diseases. Blanco Fernández calls this study plant pathology, as can be read in his work: *“Plant pathology or botanical pathology is that part of plant physics that deals with the disorders that the organs and functions of plants may experience”* [33] (p. 70) (Figure 1). This is the first time that this name was given to the study of plant diseases based on the etiologies that produce them, a name that has remained until now.

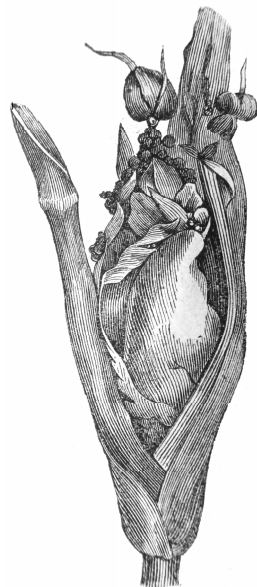


Figure 1. Engraving of an ear of corn affected by *Ustilago maydis* that appears in one of Blanco Fernández’s works published in 1857.

- In his work, De Candolle describes and groups plant diseases into 15 classes according to their causes [3] (pp. 1069–1520), while Blanco Fernández goes a step further and arranges these 15 into two sections, which are in turn divided into orders and sub-orders, a proposal which he presents to the scientific community as follows: *“In the outline of the pathological picture that I submit to the most upright criterion of the botanical republic, based on the causes that can produce alterations in plant tissue or its products, those that can determine the same should be referred to two large sections”* [33] (pp. 78–79).

- The 15 types of causal agents or etiologies presented in De Candolle's work are all external agents. Blanco Fernández adds to these etiologies the very important group of innate etiologies: *"In this series must be included all those which, working in a more or less unknown way, cannot be referred to, at least in a primitive way, the ordinary or general ones, which we will deal with in the next section. That various hereditary diseases should be admitted in plants is something that seems beyond doubt"* [33] (p. 79). The genetic study of these diseases [34–37] has been exploited by geneticists to breed new varieties of great interest in the food [38] and ornamental (variegation) sectors [39].
- Among the external disease-causing agents established by De Candolle are those derived from the phytotechnics developed by man: tillage, amendments, fertilizers, mechanical actions, etc. [3] (pp. 1247–1373). Assuming that these agents are the cause of diseases, Blanco Fernández substantially modifies this origin, attributing it to humans. He establishes a large group of diseases caused by animals, among which are mammals, where, in turn, he places man: *"In the first order of the class of mammals is the only genus that forms it, man [. . .] Well, despite all his superiority over the other created entities, he does not fail to cause enough damage to plants"* [40] (p. 150). To De Candolle's negative consideration of attributing a direct action on the development of diseases to certain labors, Blanco contrasts a possible beneficial therapeutic effect by positively modifying the physiology of plants, as can be seen in one of his works on powdery mildew of the grapevine: *"We have already indicated in the Semanario de agricultura, dealing with the usefulness of the pruning modified by Doctor Guyot, how the clusters of the fruiting branch were much less exposed to the attacks of oidium . . . "* [41] (p. 32). The anthropogenic consideration of the origin of some of the diseases suffered by plants not only deepens the reason for their etiologies but also highlights and signifies the increased possibilities of their preservation or cure [42], [43] (pp. 4–12), [44].
- De Candolle includes as causes of disease those of a physical nature, such as water or ambient temperature, capable of causing root asphyxia, frost, burns, etc., and also some work derived from phytotechnics, such as bad pruning, weeding, etc. Blanco also considers these external agents as disease producers, although he points out that certain intensities of these elements may not be the direct cause of disease, but they can have a significant influence on the pathogen: *"We will not deny the auxiliary influence that certain atmospheric conditions have on the development of the cryptogams in question, as well as various local circumstances; for it is observed that in times of fog, humidity in low and marshy places, the development of such parasites is favoured"* [40] (p. 106). However, Blanco does not limit himself to considering only negative atmospheric conditions, stating that they can also be positive: *"Rainwater that is somewhat strong, and especially if accompanied by a strong wind, is contrary to oidium [. . .] But if it falls gently, and the atmospheric heat increases, it helps the growth of cryptogams. Dew also favours its multiplication"* [45] (p. 228).

Blanco's attribution of adjuvant factors modifying the action of the pathogen for the development of diseases—the environment—is an extraordinarily valuable proposal that anticipated Ward (1888), an author who has been considered the first to relate the plant to the parasite and the environment [46] (p. 320). Ward's publication in "Disease in Plants" reads: *" . . . no disease can be efficiently caused by an organism alone, since its powers for injury as a parasite, or otherwise, are affected by its non-living environment as well as by the host plant. For instance, the spores of a parasitic fungus which would infect and rapidly destroy a potato plant in moist warm weather be showered on such a plant with impunity, if the air remains dry and cool"* [47] (p. 41).

The etiological reason Blanco used to elaborate his plant pathology, a criterion later also used by Kühn [9] (pp. 22–41), was not taken up by all scientists studying plant diseases. In England, from 1854 onward, the Reverend Miles Joseph Berkeley wrote articles in "The Gardeners Chronicle" convinced that there should be a branch of science that should be called plant pathology, a science that should follow the same principles that doctors use for the diseases of man and that he classified by their symptoms into forty-two classes including unproductiveness, old age, sunstroke, warts, etc. [48] (p. 91). Berkeley went on to

classify more than 5000 species of fungi, many of which were plant pathogens [49] (p. 229), but as far as the classification of diseases based on semiological principles was concerned, he regressed to the classifications made in the early 19th century by Von Plenck and Filippo Re.

Blanco Fernández's proposals on plant pathology were not limited exclusively to its publication as part of botany, but he also proposed its teaching in an ad hoc center: *"The Matritense Economic Society has always been constant in the principle that without enlightenment there is not and cannot be happiness in the nations; desiring for the same reason to propagate the most important lights and knowledge among all the classes of the state; and constantly trying to inspire the people with the spirit that animates this philanthropic corporation, it did not hesitate for a moment to accept the generous offer made by its individual Mr. Antonio Blanco Fernández, to publicly explain the Physiology and Pathology of plants with application to medicine and Agriculture"* [50] (p. 3).

The founding of this chair (Figure 2) shows the intention of separating the knowledge of plant diseases from botany, a fact that gives it relevance in the consideration of the genesis of plant pathology. *"The event constitutes an important date for the History of Health in Spain ... On February 11, 1838, at noon, the Chair was inaugurated in the building of the National School for the Deaf and Dumb, of the Economica Matritense ... The ceremony was presided over by Antonio Sandalio de Arias, who in 1815 created the official teaching of Agriculture in the Botanical Garden"* [4] (pp. 578–579).

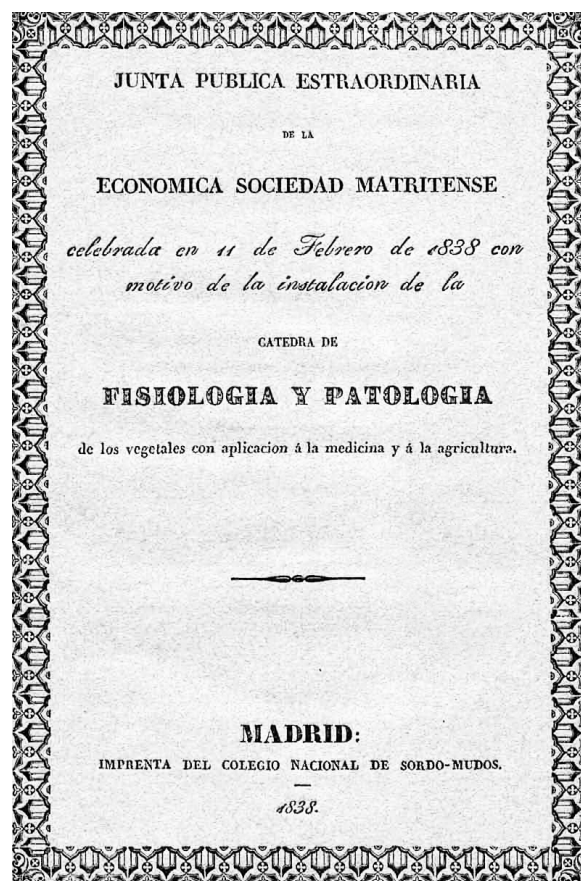


Figure 2. Publication that records the creation, in 1838, of the “Cátedra de Fisiología y Patología de los Vegetales con Aplicación a la Agricultura y a la Medicina” (Chair of Physiology and Pathology of Plants with Application to Agriculture and Medicine).

In May 1838, Blanco Fernández was appointed professor of plant physics at the University of Valencia and director of the Botanical Garden of that city, which is why he had to abandon the Chair of Plant Physiology and Pathology created in Madrid, and as he was not replaced by anyone, that institution interrupted its activity [51] (p. 268), although it reappeared at

the School of Agricultural Engineers in Madrid with the foundation, by Royal Decree of 21 January 1878, of the “Chair of Plant Pathology and its Therapeutics” [52] (p. 25).

Roberts and Boothroyd [53] (p. 20) state that “*scientific thought requires that the laws or principles of a given knowledge be embodied in a logical system*”, and when this knowledge, suitably ordered, is studied or researched in a university, center, or college, it attains the status of an academic discipline [54], a singularity that appears in Blanco’s activity from 1838 onward [55]. These university studies in human medicine and veterinary medicine in Spain, in their different historical moments, achieved a very significant development in their disciplines and a very significant consolidation with respect to their origins [5] (pp. 165–188).

Because of the quality that Blanco managed to confer on plant pathology, it has been suggested by some authors that this discipline is the origin of phytiatry: “*The phytomedical ideas of Dr. Antonio Blanco Fernández acquire the status of a body of doctrine, which schematically offers a full structure of his Phytomedicine*” [4] (p. 613). This medicine, for various reasons, was never implemented: “*There are some indications that the founders of that discipline had some scruples (such as an effort for high precision) about using the term Plant medicine. It is a fact that the newly emerging discipline did not practically have any available active substances and preparations containing active substances in the form in which they would cure diseased plants*” [56] (p. 135).

4. Birth of Experimental Plant Pathology

If it was the disease caries, which severely limited wheat harvests, that prompted Prevost’s experiments to determine the cause of the disease, it was downy mildew in potato fields that prompted some researchers to study it, thereby not only determining the pathogen that caused it but also opening up a new technological field for disease experiments.

The potato blight problem began in 1830 after potato cultivation had been fully established in Europe and the United States from the Andes, as the potato tuber had become a staple food for the population in many European regions. Cereal production was limited by climatic conditions and the crop’s own characteristics—the yield of a hectare of potato is much higher than that of wheat, and sometimes two crops of the tuber can be grown per year, whereas cereals only yield one. Between 1800 and 1845, the population of Ireland grew from 4.5 to 8 million people, and their families were fed almost exclusively on potatoes, so when downy mildew became widespread in the fields, the disease had catastrophic consequences.

“The population, which in 1846 was 8.5 million was reduced to 6.5 million, a reduction that would continue in the following years due to both mortality and emigration to America” [57] (p. 196). Botanical studies carried out to solve this problem were successful. Von Martius, in 1842, in Germany, was the first to verify the association between downy mildew and a microorganism, a relationship confirmed by Berkeley in 1846. In the same year, the Frenchman Montagne isolated the fungus, which he named *Botrytis infestans*, although it was De Bary who, from an isolate of the pathogen, reproduced the disease on leaves and tubers of the plant, which has been named “*Phytophthora infestans* (Mont.) de Bary”.

De Bary’s research was not only concerned with potato disease. In 1865, he published his research on wheat rust, confirming experimentally that the development of the fungus *Puccinia graminis* was related to barberry (*Berberis vulgaris*), which is why its removal from the vicinity of wheat fields was an extraordinary prophylactic measure for the control of the disease. Other extraordinary contributions of De Bary were the description of the sexual reproduction of fungi, as well as the discovery of the necrotrophic function of some species, by showing that *Sclerotinia sclerotiorum* releases a substance—Prospectinase—that promotes the death of plant tissues before the fungus colonizes them [58] (pp. 340–341).

De Bary’s 1853 publication “*Untersuchungen über die Brandpilze und die durch sie verurshaten Krankheiten der Pflanzen mit Rückshit auf das Getreide und andere Nutzpflanzen*” (“Investigations on charcoal and the diseases it causes in plants with respect to cereals and other crops”) was an archetype for studies on plant diseases, and by this other publication made in 1861, “The currently spreading potato disease, its cause and

its prevention. A study based on the principles of plant physiology”, De Bary has been considered the founder of experimental plant pathology by some authors [59].

De Bary was not only a great scientist but also an excellent teacher. Students from various European countries, including Darwin and Ward from England, Millardet from France, Woronin from Russia, Koch and Kühn from Germany, Farlow from the United States, and Beijerinck from Holland, came from his classrooms as professor of botany at the universities of Freiburg, Halle, and Strasbourg, where he was rector [58] (p. 338).

The extraordinary need for food in Germany to satisfy the large population in the industrial areas led to the cultivation of the sugar beet. By 1783, sugar had been obtained from the sugar beet, and by 1802, industrial production had been achieved, which made the crop of interest to farmers. Pests of various microorganisms, arthropods, and parasitic plant species appeared as the crop was intensified.

Julius Gotthelf Kühn became interested in beet diseases early on [46] (p. 316); beet and rape diseases were the subject of his doctoral thesis. From 1848 onward, he discovered fungi and nematodes pathogenic to various plant species [49] (p. 38) and, in addition to publishing articles on them, composed the first book entirely devoted to plant diseases. Since Needhman demonstrated in 1743 that *Anguina tritici* was responsible for ear-cockle disease of wheat [60], it was not until 1857, when Kühn and Davaine [61] published on *Ditylenchus dipsaci*, that nematodes were studied. Another pathogen—*Rhizoctonia solani*—which developed a disease on potatoes, was discovered by Kühn in 1858.

With the discoveries made and the knowledge that botany provided in those years, Kühn wrote and published the book “*Die Krankheiten der Kulturgewächse, ihre Ursachen und ihre Verhütung*” (“The diseases of cultivated plants, their causes and their prevention”). Kühn’s intention is stated in the foreword to the work: “*The diseases of our crops have, more than ever, attracted the attention not only of farmers and plant physiologists, but also of every thinking person. We have a rich bibliography on the individual manifestations of the disease, but there is no work that covers all of them according to the present state of our knowledge. This work can meet a real need*” [9] (p. 3).

The sources from which he drew his inspiration, as he himself states in his work, are very limited: “I found the greatest stimulus and encouragement for my study of plant diseases in the work of Schleiden, *Die Physiologie der Pflanzen und Thiere und Theorie der Pflanzencultur*, Braunschweig, 1850, and in the work of Anton de Bary, Braunschweig, 1850. *Unterfuchungen über die Brandpilze*, Berlin, 1853” [9] (p. 4).

Kühn began his book by stating: “*Plant diseases are based on abnormal changes in the physiological processes which precede them*” [9] (p. 1). The content of the book is structured in two parts, the first in which he places the diseases by their causes in three groups: climatic conditions, soil conditions, and diseases of unknown nature; the action of animals; and phanerogamous and cryptogamous parasitic plants [9] (pp. 22–41). The second is devoted to diseases specific to cereal, cruciferous, tuber and bulb crops, crops in which they caused significant production losses [9] (pp. 42–259): “*Damage to the potato from animals, especially invertebrates and insect larvae, and directly from physical influences, is usually of little importance [. . .] The leaves are sometimes attacked in large numbers by the potato aphid (Aphis solani)*” [9] (p. 198). “*The leaves of the turnips were constantly discoloured [. . .] The cause of this phenomenon was yellow-red mites which were visible to the naked eye as moving red dots and which were present in enormous numbers*” [9] (p. 231). “*Orobanche ramosa sometimes causes extraordinary damage, especially to hemp fields. As in the case of all weeds which reproduce by seed*” [9] (p. 26).

Kühn was a scientist who was also very sensitive to the consequences of diseases, which is why his studies were aimed not only at identifying parasites and understanding parasitic phenomena but also at finding ways of controlling them. He was aware of Prevost’s work in which he had discovered that copper sulphate was a toxic salt for the spores of the cryptogam that causes cereal blight (*Tilletia caries*), and based on this, Kühn found that the impregnation of cereal seeds with sulphate had a positive effect in controlling the disease [49] (p. 112). Kühn’s interest in nematodes extended to their control, and in 1871, he made the first application of a nematicide (carbon disulphide) against beet nematodes.

At the same time, Kühn and his collaborators studied numerous plant species in the interest of using them as traps, although in the end, they found that the most effective measure was crop rotation, which is still the most practical and economical of the recommended measures [62] (pp. 3–4).

5. Segregation of Experimental Plant Pathology into Pathology, Agricultural Entomology and Weed Science

Experimental studies initiated by some researchers, primarily De Bary and Kühn, were critical for the understanding of the development of plant diseases, their causes, development, and propagation, as well as various procedures for their control, resulting in a shift in the generalist conception with which plant pathology was born.

Blanco's concept of plant pathology as "the discipline which studies plant diseases due to whatever cause" was modified by several authors, who excluded animals and weeds as the cause of these diseases. With regard to tree diseases, Hartig published "Wichtige Krankheiten der Waldbäume" in 1874. In his third edition, the diseases are divided into five chapters: diseases caused by plant parasites (phanerogams and cryptogams, in which he includes myxomycetes and bacteria), damage caused by the action of noxious substances, diseases caused by soil influences, and diseases caused by wounds. He justifies this choice at the beginning of the work: "*The study of insect damage to plants has developed independently of plant pathology, and in all schools its teaching is rightly regarded as completely separate from plant pathology. That is why we shall not deal with harmful insects in this book*" [11] (p. 6).

This view of setting animals aside as the cause of plant diseases was followed by D'Arbois de Jubainville and Vesque (1878): "*We call disease the disorder which manifests itself in the organism and which prevents it from adequately fulfilling the role assigned to it [. . .] caused by the soil, the atmosphere, wounds, various causes not attributed to parasites, parasitic phanerogams and parasitic cryptogams*" [7] (pp. 1–3).

From Hartig's work published in 1874, the genesis of plant pathology began a third stage in which it was divided into three major areas of knowledge: plant pathology, or phytopathology, which is dedicated to the study of diseases caused by microorganisms and abiotic agents; agricultural entomology, which is concerned with the damage caused by animal species parasites of plants; and weed science, which is concerned with the alterations in the functioning or limitation of the productivity of plants. These are three major areas of knowledge for the study and solution of "diseases, pests, and weeds". Since their constitution, these three specializations were consolidated as new knowledge and better research procedures and tools emerged, although this fragmentation made it difficult for researchers involved in them to relate to each other, a situation that has been considered negative by some authors: "*. . . such disaggregation has been an obstacle to the use of holistic phytosanitary care in the framework of effective institutional systems at regional, national and international levels that would be comparable to human and veterinary medicine systems*" [56] (pp. 146–147).

6. Institution of Phytiatry

The generalist sense of plant pathology proposed by Blanco more than 150 years ago, which has been described as phytomedicine by some authors, disappeared as other disciplines were born from it.

Studies on diseases caused by micro-organisms in which the pathogen was recognized began with the identification of the wheat gall nematode and continued with numerous cryptogams from 1807 onward, and at the end of the century, bacteria and viruses were discovered as disease-causing organisms; by the 20th century, it was phytoplasmas and viroids.

From 1878 to 1884, in Illinois, Thomas Jonathan Burril was researching to determine the cause of some wilts that appeared in apple and pear trees, discovering that they were caused by some particles that appeared in a viscous liquid, which he called *Micrococcus amylovorus*—*Erwinia amylovora*—although it was Arthur in 1885 who was able to prove

that they were responsible for the disease [49] (p. 65). This discovery opened a field of study for Smith, who, from 1895, identified numerous species causing diseases in cereals, citrus, cucurbits, fruit trees, solanaceae, etc. He published the first book on plant diseases caused by bacteria, *Bacterial Diseases of Plants*, for which he has been considered the father of phytobacteriology.

In the second half of the 19th century, tobacco fields in Holland suffered from a disease characterized by a chlorosis of the leaves, the image of which suggested to farmers the name “tobacco mosaic”. The disease was studied by Adolf Mayer, who, in 1886, found that a fluid extracted from diseased plants was able to infect healthy plants, reproducing the symptoms of the disease. In 1892, Dimitrii Ivanowski demonstrated that this fluid could even pass through the filters used to retain bacterial cells [49] (p. 77), an extract that M.W. Beijerinck called “contagium vivum fluidum” and called “virus” for short. From it, Beijerinck isolated the organism and proved, in 1898, that it was the cause of the disease [46] (p. 324), which is why he has been considered the “father of plant virology”.

Well into the 20th century, in 1933, Knoll and Ruska presented the construction of the first electron microscope, a device that magnifies the image much more than optical microscopes, which made it possible to study organisms and morphological structures with great precision. As a result of the use of the electron microscope, Doi et al. (1967) [63] carried out research on a disease of mulberry. They discovered phytoplasmas, which are obligate parasitic organisms of plant phloem that are similar in size to viruses and are spread by insect vectors. Somewhat later, Diener (1973) [64], investigating a potato disease known as “spindle tuber”, discovered viroids, infectious agents made up of ribonucleic acid (RNA) molecules.

These discoveries, which were made within the field of plant pathology, gave rise to other disciplines, a tendency toward specialization that has been applied even to the class of plants to which they refer, with some authors justifying the existence of a pathology dedicated exclusively to forest species: “*Forest pathology has obvious common roots with plant pathology, but it is not simply one of its specialties [. . .] forest pathology, as a specialty of forestry, has had a tradition of systemic and long-term thinking and, probably more and earlier than plant pathology, an ecological approach*” [65] (p. 46).

This specialization of disciplines studying various aspects of disease also appeared in entomology and weed science from the 19th century onward.

In the field of agricultural entomology, there have also been important milestones since the mid-19th century that have led to the birth of other disciplines. Since Agostino Bassi discovered in 1834 that the silkworm disease muscardine was caused by the fungus *Beauveria bassiana*, biological control experiments against insect pests have begun [66] (p. 3); however, probably the most significant milestone for the control of arthropod pests was the control of phylloxera (*Daktulosphaira vitifoliae*), an epiphytotic vine disease that devastated a large part of the vineyards of Europe and which, by means of phytotechnical measures, was brought under control [67] (p. 536).

With regard to the discoveries made in the discipline of weed science, the most significant milestone occurred in the 20th century, when in the mid-1940s, the hormonal herbicides 2,4-D and MCPA were discovered, products that destroyed certain species of dicotyledons and respected narrow-leaved crops [68].

Since the transformation of the generalist sense with which plant pathology was born into three specialties—pathology, entomology, and weed science—the study centers that were created no longer had the integrating character of the Chair for the Study of Plant Physiology and Pathology, created in Madrid in 1838, and which was continued in the Chair of Plant Pathology of the School of Agricultural Engineers of Madrid, founded in 1878.

Kühn’s interest in nematodes led him to specialize in them, and in 1891, on his initiative, the “Versuchsstation für Nematodenvertilgung und Pflanzenschutz” (Experimental Station for Nematode Eradication and Plant Protection) was established in Halle (Saxony) [49] (p. 198). It was probably the first center for the study of a special group of

pathogens that, despite being animals, were included in the field of plant pathology or phytopathology because of their microscopic nature.

In 1894, the private foundation Willie Commelin Scholten established a plant pathology laboratory—the Willie Commelin Scholten Phytopathological Laboratory—in Amsterdam. This was one of the first institutes in the world dedicated to scientific research and higher education in plant pathology [69] (p. 667); in 1899, the first department dedicated to the study of plant diseases and pests was established in the Czech Republic at the Agricultural Research Station in Prague [70] (p. 6). In 1907, in the USA, a Department of Plant Pathology was founded at Cornell University; the next one was founded two years later at the University of Wisconsin, followed by others at the Universities of California (Berkeley), Illinois (Urbana), Minnesota (St. Paul's), and Washington (Pullman) [49] (p. 226).

Until 1900, Western European countries were still at the forefront of research, but they received a setback during the First World War that the United States did not suffer, as a result of which the pathology centers in the United States have become world reference centers [49] (p. 330).

In 1998, Browning, president of the enterprising APS (American Phytopathological Society), published an article in which, reflecting on the world population, he warned of the inability of agriculture to feed humanity in the 21st century—in 2050, the world population is estimated to be 9.7 billion [71]—due to the difficulty of increasing agricultural production [72], a problem exacerbated by climate change denounced by various institutions [73]. As a solution to this dilemma, and in view of the fact that the diseases suffered by cultivated plants cause considerable losses, he proposed that these losses could be avoided by creating a structure in which all existing disciplines whose more or less preferential interest plant health could be articulated, an idea that, with nuances, is still being called for today [74,75].

It is unquestionable that the extraordinary complexity of the new techniques used in the field of plant diseases requires a high level of specialization, and it is very difficult for these specialists to maintain, at the same time, the same level of interest and knowledge concerning the diseases. It is a fact that these specialists prefer to direct their attention to the specialty in which they work rather than to plant diseases, a behavior that occurs in this field of research in the USA: *“Just as plant pathology broke away from traditional botany at the end of the century, the nematologists long ago established their own professional society. Most plant virologists prefer to lead a separate existence. Similarly, many of the molecular biologists in plant pathology departments in this country do not attend the annual meetings of the American Phytopathological Society (APS) and prefer to meet with other molecular biologists”* [76] (p. 6).

This proliferation of new specialties that emerged as a result of scientific advances in the second half of the last century harmed the three that were established at the beginning of the twentieth century: pathology, entomology, and weed science. One of its consequences has been the dissolution of pathology and entomology departments in several universities [76] (p. 12), [77] (p. 2). On the other hand, since the end of the 20th century, the number of teaching hours devoted to the knowledge related to them has been reduced, which has made them less effective in achieving crop health and, consequently, the maintenance of crop productivity in a sustainable way [77] (p. 2), [70] (p. 3), [78] (pp. 11–112), [79,80] (pp. 579–580).

Nowadays, there are very serious pests in the form of arthropods, plant pathogens, and weeds [81], a seriousness exacerbated by environmental and social conditions, the solution to which is usually addressed with the exclusive use of pesticides, a strategy that leads to the development of resistant parasites [82]. This problem, together with the lack of effectiveness that plant health disciplines were showing at the end of the 20th century, led Professor Agrios (University of Florida) to introduce postgraduate studies for the degree of “doctor of plant medicine” at the University of Florida, an initiative that, as a university degree, has been extended to other universities on different continents [14] (pp. 1192–1193) and which is in great demand: *“Scientifically qualified specialists able to work as phyiatry (plant medicine) doctors are needed world-wide [. . .] as a University multidisciplinary science could include several*

agronomical and biological scientific disciplines, having as core phytopathology, entomology and nematology, weed science and phytopharmacy, soil management and fertilizers, etc. to install a five-year University course as stands for Veterinary Medicine internationally” [15] (p. 95).

On the other hand, the practical application of phytiatry through concrete programs of work through clinics and plant doctors has demonstrated its necessity and effectiveness in terms of agroecosystems and environmental sustainability, as well as food security [14], [83,84] integrating phytiatry as an indispensable part of a single global health concept [85] that allows us to face the important challenges we are facing globally [86]

7. Final Considerations

The extraordinary contribution of De Bary and Kühn’s works to the knowledge of plant diseases has led researchers of the history of plant pathology to believe that this scientific discipline began with the works of these authors and to give little value to or ignore the contributions of others, including De Candolle and Dr. Blanco, a lack of knowledge that prevents the precise genesis of plant pathology from being established.

The studies that Blanco published on plant diseases under the name of plant pathology were the first studies devoted to systematizing diseases by the causes that produced them, both biotic and abiotic, studies that appeared just after those that had been built on semiological principles. Blanco’s studies were not only published, but the first chair that we know of was created for this purpose, characteristics that, since then, have allowed us to classify plant pathology as an academic discipline.

The results of this review of the genesis of plant pathology show that there are three distinct stages in its formation from the 18th century onward:

1. In the first stage, plant diseases were attributed to the weaknesses that, due to various environmental causes, plants experienced in their development, as is verified in the publications of Palau and Verdera [20] and Adanson [21], among others.
2. The second stage was the appearance of plant pathology as an academic discipline whose objective was the knowledge of diseases due to any of the biotic or abiotic causes that produce them, knowledge that was taught in a specific chair. This stage began with Blanco Fernández (1838–1846) and continued with De Bary (1853) and Kühn (1858).
3. The third stage was the development of plant pathology or phytopathology dedicated to the study of diseases caused exclusively by micro-organisms and abiotic agents. This stage began with the publications of Hartig in 1874, where insects were excluded, and of D’Arbois of Jubainville and Vesque in 1878, which separated entomology, pathology, and malherbology directly.

The determination of these stages modifies the knowledge we had until now of the genesis of plant pathology, but in addition, it is verified that the second of the stages indicated, the study of plant diseases due to any cause that produces them, coincides in its approach with the range of diseases to be studied by phytiatry.

The evidence of this fact shows that having ignored elements of the genesis of plant pathology, as well as some of its characters of the second defined stage, such as De Candolle and Blanco Fernández and their contributions, deviated the development of plant pathology that was proposed at that time and that two centuries later is considered indispensable for the sustainable development of agronomy.

Author Contributions: Conceptualization, J.D.M.d.l.V. and J.D.M.M.; methodology, J.D.M.d.l.V.; software, J.D.M.M.; formal analysis, J.D.M.d.l.V.; investigation, J.D.M.d.l.V. and J.D.M.M.; resources, J.D.M.d.l.V. and J.D.M.M.; data curation, J.D.M.d.l.V.; writing—original draft preparation, J.D.M.d.l.V. and J.D.M.M.; writing—review and editing, J.D.M.d.l.V. and J.D.M.M.; supervision, J.D.M.d.l.V. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data sharing is not applicable to this article.

Acknowledgments: We are grateful to the Instituto de Estudios Giennenses (IEG) as well as to the Real Sociedad Económica Matritense de Amigos del País (RSEMAP) and the Sociedad Española de Sanidad Vegetal (AESAVE) for making available their non-digitized sources of information.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zadoks, J.C.; Koster, L.M. A Historical Survey of Botanical Epidemiology. In *A Sketch of the Development of Ideas in Ecological Phytopathology*; Veenman: Wageningen, The Netherlands, 1976.
2. Prevost, B. *Memoire Sur La Cause Immediate De La Carie Ou Charbon Des Bles: Et De Plusieurs Autres Maladies Des Plantes, Et Sur Les Preservatifs De La Carie*; Chez Bernard Imprimeur-Libraire: Paris, France, 1807.
3. De Candolle, A.P. *Cours de Botanique. Seconde Partie. Physiologie Végétale, Ou Exposition Des Forces et Des Fonctions Vitales Des Végétaux*; Béchet Jeune, Libraire de la Faculté de Médecine: Paris, France, 1832.
4. Merck-Luengo, J.G. Aportaciones a La Historia de La Sanidad Vegetal En España. Una Epifitia y Un Fitomédico Del s.XIX: El Oidio y Antonio Blanco Fernández. Ph.D. Thesis, Escuela Técnica Superior de Ingenieros Agrónomos, Madrid, Spain, 1982.
5. Del Moral Martínez, J. La Sanidad Vegetal en España y el Papel de la Fisiología en su Planteamiento de Futuro. Ph.D. Thesis, Universidad de Extremadura Facultad de Ciencias, Badajoz, Spain, 2016.
6. Berkeley, M.J. Observations, Botanical and Physiological on the Potato Murrain. *J. Hortic. Soc. Lond.* **1948**, *1*, 9–34.
7. De Jubainville, M.A.D.A.; Vesque, J. *Les Maladies Des Plantes Cultivées, Des Arbres Fruitières et Forestiers Produites Par Le Sol—l’atmosphère—Les Parasites Végétaux, Etc. d’après Les Travaux de Tulasne, de Bary, Berkeley, Hartig, Sorauer, Etc*; Rothschild, Éditeur: Paris, France, 1878.
8. De Bary, A. *Untersuchungen Über Die Brandpilze Und Die Durch Sie Verursachten Krankheiten Der Pflanzen Mit Rücksicht Auf Das Getreide Und Andere Nutzpflanzen*; von Verlag, G.W.F., Ed.; Müller: Berlin, Germany, 1853.
9. Kühn, J.G. *Die Krankheiten der Kulturgewächse: Ihre Ursachen und ihre Verhütung*; Bosselmann, G.: Berlin, Germany, 1858.
10. Whetzel, H.H. *An Outline of the History of Phytopathology*; W.B. Saunders: Philadelphia, PA, USA, 1918; pp. 1–138.
11. Hartig, R. *Tratado de Las Enfermedades de Las Plantas y Principalmente de Las Que Atacan Los Árboles Forestales (Traducción J.M^a Castellarnau) (Trabajo Original de Una Primera Edición Publicada En 1882)*; Imprenta Alemana: Madrid, Spain, 1908.
12. Jiménez Díaz, R.M.; Castillo, P.; García-Arenal, F.; García Marí, F.; Montesinos Seguí, E.; Recasens Guinjuan, J. Enfermedades, Plagas y Malas Hierbas Que Constituyen Problemas de Carácter Estratégico En Sectores Productivos y Masas Forestales Claves Para La Economía Española. In *Libro Blanco de la Sanidad Vegetal en España*; Jiménez Díaz, R.M., López González, M.M., Eds.; UCO Press: Córdoba, Spain, 2019; pp. 317–386.
13. Flood, J. The importance of plant health to food security. *Food Sec.* **2010**, *2*, 215–231. [CrossRef]
14. McGovern, R.J.; To-Anun, C. Plant doctors: A critical need. *IJAT* **2016**, *12*, 1177–1195. Available online: https://www.researchgate.net/publication/313247994_Plant_Doctors_A_Critical_Need (accessed on 18 March 2023).
15. Tjamos, E.C. The Introduction of Phytiatry (Phytiatry) in Universities as a distinct science, is a primary necessity for food security and modernization of global agricultura. *Hortic. Int. J.* **2018**, *2*, 95–101. [CrossRef]
16. Deguine, J.P.; Aubertot, J.N.; Flor, R.J.; Lescourret, F.; Wyckhuys, K.A.; Ratnadass, A. Integrated pest management: Good intentions, hard realities. *A review. Agron. Sustain. Dev.* **2021**, *41*, 38. [CrossRef]
17. Gest, H. The Discovery of Microorganisms Revisited—A Close Reading of 17th-Century Documents Shows That Hooke, Rather than Leeuwenhoek, Was the First to Observe a Microorganism. *ASM* **2004**, *70*, 269–274.
18. Egerton, F.N. A History of the Ecological Sciences, Part 29: Plant Disease Studies During the 1700s. *Bull. Ecol. Soc. Am.* **2008**, *89*, 231–244. [CrossRef]
19. Vidhyasekaran, P. *Concise Encyclopedia of Plant Pathology*; CRC Press: Boca Raton, FL, USA, 2014.
20. Palau y Verdura, A. *Explicacion de la Filosofia y Fundamentos Botanicos de Linneo, Con la Que se Aclaran y Entienden Facilmente las Instituciones Botanicas de Tournefort*; Antonio de Sancha: Madrid, Spain, 1778.
21. Adanson, M. *Families des Plantes*; Chez Vincent, Imprimeur: Paris, France, 1763.
22. Von Plenck, G.G. *Fisiologia e Patologia Delle Pianta*; Giannantonio Pezzana: Venecia, Italy, 1798.
23. Re, F. *Saggio Teorico-Pratico Sulle Malattie Delle Pianta*; Per Giovanni Silvestri: Venecia, Italy, 1817.
24. Boitard, C. *Manuel Complete de Botanique*; Roret Libraire: Paris, France, 1828.
25. Tillet, M. *Dissertation Sur La Cause Qui Corrompt et Noircit Les Grains de Blé Dans Les Épis; et Sur Les Moyens de Prévenir Ces Accidents*; Chez la Veuve de Pierre Brun: Burdeos, France, 1755.
26. Tessier, A.H. *Traité des Maladies des Grains*; La Veuve Herissant, Imprimeur-Libraire y Théophile Barrois: Jeune, France, 1783.
27. Robles, M.; Antonio, F. *Disertacion Sobre Las Enfermedades Del Trigo, Cebada, Maiz, Arroz y Demas Cereales*; Imprenta de la Calle de la Greda: Madrid, Spain, 1819.
28. Franz, U. *Die Exantheme der Pflanzen und Einige Mit Diesen Verwandte Krankheiten der Gewächse Pathogenetisch und Nosographisch Dargestellt*; Wien, G.C., Ed.; Antiquariat im Hufelandhaus GmbH vormals Lange & Springer: Berlin, Germany, 1833.
29. Philippiar, F.H. *Traité Organographique et Physiologico-Agricole sur la Carie, le Charbon, l’ergot, la Rouille et Autres Maladies de Même Genre qui Ravagent les Céréales*; Marlin, V., Ed.; Imprimeur de la Société Royale d’Agriculture et des Arts de Seine et Oise: Paris, France, 1837.

30. Prillieux, É.-E. *Maladies Des Plantes Agricoles et Des Arbres Fruitières et Forestiers Causées Par Des Parasites Végétaux*; Librairie de Firmin—Didot et Cie: Paris, France, 1895; Volume 1, pp. 1–452.
31. Re, F. Saggio di Nosologia Vegetabile di Filippo Rè Cavaliere del r. Ordine Della Corona di Ferro e P-Prof. Di Agricoltura nella R. Università di Bologna. Operetta Utile ai Botanici ed Agli agricoltori; Presso Giuseppe Tofani e Comp.: 1807. Available online: <https://binp.regione.veneto.it/SebinaOpac/resource/elementi-dagricoltura-di-filippo-re-cavaliere-dellordine-della-corona-di-ferro-professore-nella-r-un/VIA0415238> (accessed on 1 March 2023).
32. De la Vega, J.D.M.; del Moral Martínez, J. El Dr. Antonio Blanco Fernández, Natural de Segura de La Sierra (Jaén), Científico Destacado Del Siglo XIX. *Boletín Inst. Estud. Giennenses* **2021**, *223*, 201–240.
33. Blanco Fernández, A. *Botánica I, II y III*; Imprenta y Librería de Boix: Madrid, Spain, 1845.
34. Israeli, Y.; Lahav, E. Genetic abnormalities of banana. In *Handbook of Diseases of Banana, Abacá and Enset*; CAB International: Wallingford, UK, 2019; pp. 546–566.
35. Bogdanova, V.S. Genetic and molecular genetic basis of nuclear-plastid incompatibilities. *Plants* **2019**, *9*, 23. [\[CrossRef\]](#)
36. Gradziel, T.; Fresnedo, J. Noninfectious bud-failure as a model for studying age related genetic disorders in long-lived perennial plants. *J. Amer. Pom. Soc.* **2019**, *73*, 240–253.
37. Zhao, M.H.; Li, X.; Zhang, X.X.; Zhang, H.; Zhao, X.Y. Mutation mechanism of leaf color in plants: A review. *Forests* **2020**, *11*, 851. [\[CrossRef\]](#)
38. Mackelprang, R.; Lemaux, P.G. Genetic engineering and editing of plants: An analysis of new and persisting questions. *Annu. Rev. Plant Biol.* **2020**, *71*, 659–687. [\[CrossRef\]](#)
39. Zhang, J.H.; Zeng, J.C.; Wang, X.M.; Chen, S.F.; Albach, D.C.; Li, H.Q. A revised classification of leaf variegation types. *Flora* **2020**, *272*, 151703. [\[CrossRef\]](#)
40. Blanco Fernández, A. *Curso Completo de Botánica I y II*; Juan Oliveres, D., Ed.; Impresor de S.M.: Barcelona, Spain, 1851.
41. Blanco Fernández, A. *Del Oidio tukeri y del Azufrado de las Vides*; Imprenta de Manuel Galiano: Madrid, Spain, 1862.
42. Thurston, H.D. *Sustainable Practices for Plant Disease Management in Traditional Farming Systems*; CRC Press: Boca Raton, FL, USA, 2019; p. 309. [\[CrossRef\]](#)
43. Deguine, J.P.; Aubertot, J.N.; Bellon, S.; Côte, F.X.; Lauri, P.E.P.E.; Lescourret, F.; Ratnadass, A.; Scopel, E.; Andrieu, N.; Bàrberi, P.; et al. Agroecological crop protection for sustainable agriculture. *Adv. Agron.* **2023**, *178*, 1–59. [\[CrossRef\]](#)
44. Ramirez-Santos, A.G.; Ravera, F.; Rivera-Ferre, M.G.; Calvet-Nogués, M. Gendered traditional agroecological knowledge in agri-food systems: A systematic review. *J. Ethnobiol. Ethnomed.* **2023**, *19*, 11. [\[CrossRef\]](#)
45. Blanco Fernández, A. *Tratado Sobre El Cultivo de La Vid y Elaboración de Vinos*; Establecimiento Tipográfico de T. Fortanet: Madrid, Spain, 1863.
46. Egerton, F.N. History of Ecological Sciences, Part 44: Phytopathology during the 1800s. *Bull. Ecol. Soc. Am* **2012**, *93*, 303–339. [\[CrossRef\]](#)
47. Ward, H.M. *Disease in Plants*; Macmillan & Co.: London, UK, 1901.
48. Large, E.C. The Advance of the Fungi. In *The Advance of the Fungi*; Jonathan Cape: London, UK, 1940.
49. Ainsworth, G.C. *Introduction to the History of Plant Pathology*; Cambridge University Press: Cambridge, UK, 1981.
50. Real Sociedad Económica Matritense de Amigos del País; Guerra, F.; de los Herreros, B.; Corradi, F.; de Arias y Costa, A.S.; Blanco Fernández, A.; Colegio Nacional de Sordomudos y de Ciegos. *Junta Pública Extraordinaria de La Sociedad Economica Matritense: Celebrada En 11 de Febrero de 1838 Con Motivo de La Instalacion de La Catedra de Fisiologia y Patologia de Los Vegetales Con Aplicacion a La Medicina y a La Agricultura*; S.N. Imprenta del Colegio Nacional de Sordo-Mudos: Madrid, Spain, 1838.
51. Negrín Fajardo, O. Preocupación científica en la Sociedad Económica Matritense en el siglo XIX. In Proceedings of the Actas II Congreso de la Sociedad Española de Historia de las Ciencias, Jaca, Spain, 27 September–1 October 1982; Sociedad Española de Historia de las Ciencias y de las Técnicas, SEHCYT: Logroño, Spain, 1984; Volume 2, pp. 263–278.
52. Azcárate Luxan, I. *Plagas Agrícolas y Forestales En España (Siglos XVIII y XIX)*; Serie Estudios; Ministerio de Agricultura, Pesca y Alimentación: Madrid, Spain, 1996; ISBN 84-491-0270-7.
53. Roberts, D.A.; Boothroyd, C.W. *Fundamentals of Plant Pathology*; W. H. Freeman and Co.: San Francisco, CA, USA, 1984; p. 442.
54. López Bonilla, G. Prácticas disciplinares, prácticas escolares: Qué son las disciplinas académicas y cómo se relacionan con la educación formal en las ciencias y en las humanidades. *Rev. Mex. Investig. Educ* **2013**, *18*, 383–412.
55. Del Moral Martínez, J.; Del Moral De la Vega, J. El Dr. Antonio Blanco Fernández, Posible Fundador de La Patología Vegetal Como Disciplina Científica. In Proceedings of the XX Congreso de la Sociedad Española de Fitopatología (SEF), Universitat Politècnica de València, Valencia, Spain, 24–26 October 2022; p. 345.
56. Kúdela, V. On the Need for Revision of Some Names of Plant Health Malfunctions and Their Categorisation. *Plant Prot. Sci.* **2011**, *47*, 133–148. [\[CrossRef\]](#)
57. Bartolomé García, T.; Coletto Martínez, J.M.; Velázquez Otero, R. *Historias de Plantas I: La Historia de La Patata*; Coletto Martínez, J.M., González Blanco, R., De Muslera Pardo, E., Pulido García, F., Eds.; Fundación Caja de Badajoz: Badajoz, Spain, 2014.
58. Moura, R.M.D. Relembrando Anton de Bary e sua obra fitopatológica. *Fitopatol. Bras.* **2002**, *27*, 337–343. [\[CrossRef\]](#)
59. Kutschera, U.; Hossfeld, U. Physiological Phytopathology: Origin and Evolution of a Scientific Discipline. *J. Appl. Bot. Food Qual.* **2012**, *85*, 1–5.
60. Ferraz, L.; Brown, D.J.F. *Nematologia de Plantas: Fundamentos e Importância*; Norma Editora: Manaus, Brasil, 2016.
61. Davaine, C. *Recherches Sur L'Angillule Du Blé Niellé*; Librairie de l'Academie Imperiale de Médecine: Paris, France, 1857.

62. Thorne, G. *Principles of Nematology*; McGraw-Hill Publication in the Agricultural Sciences; McGraw-Hill: New York, NY, USA, 1961.
63. Doi, Y.; Teranaka, M.; Yora, K.; Asuyama, H. Mycoplasma- or PLT Group-like Microorganisms Found in the Phloem Elements of Plants Infected with Mulberry Dwarf, Potato Witches' Broom, Aster Yellows, or Paulownia Witches' Broom. *Jpn. J. Phytopathol.* **1967**, *33*, 259–266. [\[CrossRef\]](#)
64. Diener, T.O. Viroids. In *Advances in Virus Research*; Smith, K.M., Lauffer, M.A., Bang, F.B., Eds.; Academic Press: Cambridge, MA, USA, 1972; Volume 17, pp. 295–313.
65. Desprez-Loustau, M.L.; Aguayo, J.; Dutel, C.; Hayden, K.J.; Husson, C.; Jakushkin, B.; Marçais, B.; Piou, D.; Robin, C.; Vacher, C. An Evolutionary Ecology Perspective to Address Forest Pathology Challenges of Today and Tomorrow. *Ann. For. Sci.* **2016**, *73*, 45–67. [\[CrossRef\]](#)
66. Jacas, J.A.; Urbaneja, A. *Control Biológico de Plagas Agrícolas*; Phytoma: Valencia, Spain, 2008.
67. Muñoz Del Castillo, J. *La Plaga Filoxérica. Tercera Parte. Las Vides Americanas [. . .] Segunda Edición*; Imp. y Encuad. de Federico Sanz, Compañía: Logroño, Spain, 1878.
68. Slade, R.E.; Templeman, W.G.; Sexton, W.A. Plant-Growth Substances as Selective Weed-Killers Differential Effect of Plant-Growth Substances on Plant Species. *Nature* **1945**, *155*, 497–498. [\[CrossRef\]](#)
69. Schippers, B.; Roosje, G.S. Hundred Years of History and the Future of the Foundation 'Willie Commelin Scholten Phytopathological Laboratory'. *Eur. J. Plant Pathol.* **1997**, *103*, 667–671. [\[CrossRef\]](#)
70. Kúdela, V. Plant Pathology in the Czech Republic. *Plant Prot. Sci.* **2002**, *38*, S1–S8. [\[CrossRef\]](#)
71. Nations, U. Población. Naciones Unidas. Available online: <https://www.un.org/es/global-issues/population> (accessed on 25 February 2023).
72. Browning, J.A. One Phytopathologist's Growth through IPM to Holistic Plant Health: The Key to Approaching Genetic Yield Potential. *Annu. Rev. Phytopathol.* **1998**, *36*, 1–24. [\[CrossRef\]](#)
73. FAO. Climate Change and Food Systems: Global Assessments and Implications for Food Security and Trade. *Policy Support and Governance. Food and Agriculture Organization of the United Nations*. Available online: <https://www.fao.org/policy-support/tools-and-publications/resources-details/es/c/435192/> (accessed on 25 February 2023).
74. Fletcher, J.; Gamliel, A.; Gullino, M.L.; McKirdy, S.J.; Smith, G.R.; Stack, J.P.A. Fresh Look at Graduate Education in Plant Pathology in a Changing World: Global Needs and Perspectives. *J. Plant Pathol.* **2020**, *102*, 609–618. [\[CrossRef\]](#)
75. Jeger, M.; Beresford, R.; Bock, C.; Brown, N.; Fox, A.; Newton, A.; Vicent, A.; Xu, X.; Yuen, J. Global Challenges Facing Plant Pathology: Multidisciplinary Approaches to Meet the Food Security and Environmental Challenges in the Mid-Twenty-First Century. *CABI Agric. Biosci.* **2021**, *2*, 20. [\[CrossRef\]](#)
76. Sequeira, L. Legacy for the Millennium: A Century of Progress in Plant Pathology. *Annu. Rev. Phytopathol.* **2000**, *38*, 1–17. [\[CrossRef\]](#)
77. Weinhold, A.R. Plant Pathology: A Discipline at a Crossroads. *Annu. Rev. Phytopathol.* **1996**, *34*, 1–11. [\[CrossRef\]](#)
78. Albajes, R.; Guinjuan, J.; Manuel, R.; Jiménez-Díaz, R. Formación Universitaria y o Universitaria En Sanidad Vegetal. In *Libro Blanco de la Sanidad Vegetal en España*; UCO Press y AESaVe: Córdoba, Spain, 2019; pp. 103–138.
79. Jiménez Díaz, R.; López González, M.M. Conclusiones Generales y Propuestas de Acción. In *Libro Blanco de La Sanidad Vegetal En España*; Jiménez Díaz, R.M., López González, M.M., Eds.; UCO Press & Editorial Universidad de Córdoba: Córdoba, Spain, 2019; pp. 677–692.
80. Recasens, J.; Albajes, R.; Jiménez Díaz, R. Mejoras En La Formación Universitaria En Sanidad Vegetal. In *Libro Blanco de la Sanidad Vegetal en España*; Jiménez Díaz, R.M., López González, M.M., Eds.; UCO Press: Córdoba, Spain, 2019.
81. Savary, S.; Willocquet, L.; Pethybridge, S.J.; Esker, P.; McRoberts, N.; Nelson, A. The Global Burden of Pathogens and Pests on Major Food Crops. *Nat. Ecol. Evol.* **2019**, *3*, 430–439. [\[CrossRef\]](#)
82. Collignon, P.J.; McEwen, S.A. One Health-Its Importance in Helping to Better Control Antimicrobial Resistance. *Infect. Dis. Trop. Med.* **2019**, *4*, 22. [\[CrossRef\]](#)
83. Powell, A. CABI's innovative use of technology, data, and knowledge transfer to reduce crop losses in the developing world. *Food Energy Secur.* **2017**, *6*, 94–97. [\[CrossRef\]](#)
84. Toepfer, S.; Zhang, T.; Wang, B.; Qiao, Y.; Peng, H.; Luo, H.; Wan, X.; Gu, R.; Zhang, Y.; Ji, H.; et al. Sustainable pest management through improved advice in agricultural extension. *Sustainability* **2020**, *12*, 6767. [\[CrossRef\]](#)
85. Garcia, S.N.; Osburn, B.I.; Jay-Russell, M.T. One health for food safety, food security, and sustainable food production. *Front. Sustain. Food Syst.* **2020**, *4*, 1. [\[CrossRef\]](#)
86. Gullino, M.L.; Albajes, R.; Al-Jboory, I.; Angelotti, F.; Chakraborty, S.; Garrett, K.A. Climate Change and Pathways Used by Pests as Challenges to Plant Health in Agriculture and Forestry. *Sustainability* **2022**, *14*, 12421. [\[CrossRef\]](#)

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.