On the Need for Revision of Some Names of Plant Health Malfunctions and their Categorisation

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Abstract

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The development of branches dealing with plant health science and plant health care proceeded more or less in three separate disciplines dealing with microbial plant pathogens (plant pathology), animal pests (applied entomology, etc.) and weeds (weed science). It resulted in disunity in concepts of basic terms such as disease, disorder and injury, in different approaches to categorisation and naming of the main types of plant health problems, and in ambivalence in the use of names for plant malfunctions of abiotic origin. Different terms are used with varying frequency for denoting the same phenomenon. The tenor of this article is to submit some suggestions for redefinition of the main types of plant health problems, their new classification and categorisation. We used the following criteria for classification of a wide spectrum of plant health problems: origin of causal agent, the mechanism by which the causal agent disrupts plant health, and epidemiological features. After the analysis of common and different properties of particular plant health problems and relationships between them, we categorised them using three neologisms, namely bioticosis, abioticosis and co-abio-bioticosis. Redefinitions of the main types of plant health problems are presented. A polyfunctional role of animal pests in plant malfunctions is discussed. Besides, examples of proposed common names for plant malfunctions caused by abiotic agents are given. The objective of the submitted suggestions is to support efforts aimed at conceptual, nomenclatural and institutional unification of plant medicine as a theoretical/practical branch.

Keywords: conceptualisation of plant disease; disease categorisation; terminological neologisms; common names of abiotic malfunctions; plant medicine

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1 Introduction

In any field of science, the consistency in the use of terminology is thought to be an important requirement for intercommunication. Discipline or branch dealing with plant health concentrates on interactions of seed plants with potentially harmful biotic and abiotic agents to prevent the disturbing of their health, to restore their health and to minimise damage due to health malfunctions by treatment measures. Like in any other specialized subject, terms in the discipline dealing with plant health malfunctions need periodic revision to fulfil the need for a uniform and standard nomenclature based on carefully reasoned and clearly defined principles. New knowledge, concepts and data continuously arise to alter our views of what has hitherto been accepted. A requirement for new categorisation of both still used and newly introduced terms may also be triggered. Besides, it is astonishing or peculiar when the branch that was established as a science and profession more than one century ago does without commonly acceptable or hardly queried name.

In this article we shall attempt to focus on selected topics related to such problems as: (*i*) the pertinent name for the branch which would include both plant health study (science) and control of plant diseases, pests and weeds (plant health care); (*ii*) different approaches to naming and categorisation of the main types of plant health problems; (*iii*) disunity in concepts of basic terms in plant pathology such as disease, disorder and injury; (*iv*) ambivalence in using the names of plant health problems of abiotic origin.

The objective of this article is: (*i*) to redefine some main types of some plant health problems; (*ii*) to submit some suggestions for a new categorisation of the main types of plant health problems; (*iii*) to give reasons for establishing rules of nomenclature of abiotic plant health problems and to propose such rules.

2 Terminological problems that need to be solved

2.1 The pertinent name for the branch dealing with plant health malfunctions and their control

The branch dealing with plant health malfunctions and their control, recently named as plant pathology, has much in common with veterinary medicine and human medicine. All three branches study interactions of eukaryotic organisms with potentially harmful biotic and abiotic agents with the basic purpose to prevent the disturbing of their health, to restore their health and to minimise damage due to health malfunctions by treatment. Human medicine and veterinary medicine are branches which have a firm position in the system of life sciences and health sciences while in the branch dealing with plant health it is quite otherwise.

2.1.1 Is there a more appropriate name instead of plant pathology?

According to Agrios (2005), plant pathology is for plants largely what medicine is for humans and veterinary medicine is for animals. However, such plant pathology definition appears to be contentious and cannot be regarded as analogous to the terms plant medicine and veterinary medicine for semantic and purely practical reasons.

The word *pathology* (derived from Gr. *pathos* = suffering, disease; *logos* = science) is defined as the study and diagnosis of disease and the word pathology is the name only for one of the medical specialties, namely the specialty dealing with the study and diagnosis of disease (http://en.wikipedia.org/wiki/Patology – accessed 2010-10-14).

The word medicine (derived from the Latin *ars medicina*) means the art of healing. Contemporary medicine treats injury and disease, typically through medication, surgery, or some other form of therapy (http://en.wikipedia.org/wiki/Medicine – accessed 2010-10-11).

It is evident from the above-mentioned definitions that no treating of diseased or sickened human, animal or plant is involved in the term pathology.

Plant pathology was defined as a science at the turn of the 20th century (Whetzel 1918). During the 20th century, search for the name of the branch was done which would include both plant health study and plant health care or which would emphasise the control of plant diseases, pests and weeds. At that time, and also later, such names as Phytopathology and Plant Protection, Plant Protection, Plant Medicine, Phytiatry, Phytomedicine, Integrated Pest Management, Plant Health, Plant Health Sciences have appeared in different countries and various languages. The term "plant protection" infers that the action taken usually

precedes the event and that the approach to control will be for protection against all anticipated hazards in a systematic, planned way (Tammen, Wood 1977).

In the second half of the 19th century and in the first quarter of the 20th century, at the beginning of the establishing of plant pathology, there are some indications that 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. The first plant pathologists could not sense that, at the turn of the 21st century, their succeeding generations would have approximately the same methods both for diagnosis of causal agents of diseases and disease curing through medication (medical treatment).

2.1.2 Why not plant medicine?

To sum up the above-mentioned, the term plant medicine is analogous to the terms such as human medicine and veterinary medicine and denotes that the field of endeavour is concerned with the diagnosis, prognosis, prescription, and control of abiotic ailments, diseases, pests and weeds (Grossmann 1971; Tammen &Wood 1977). In this broad sense, plant medicine can be regarded as an integral part of health sciences and life sciences. But if we consult a dictionary or Wikipedia, currently the most popular general reference work on the Internet, we can see that the entry plant pathology (as defined above) does not figure either in the entry health science or life science. The question arises about reasons for such state. Simple and clear answers do not exist. One may be embarrassed by the term plant medicine because of its possible confusion with such terms as herbal medicine, medical plants (as the actual plants themselves), or plant medicine (as preparations made from herbal plants). However, the homonymy of plant medicine term cannot be disqualifying for its use in a discipline dealing with plant health malfunctions.

Recent definition of human medicine on the Web runs as follows: Medicine is the art and science of healing. It encompasses a range of health care practices evolved to maintain and restore health by the prevention and treatment of illness en.wikipedia.org/wiki/Human_medicine.

Similarly like human and veterinary medicines, plant medicine can be defined as the art and science that deal with diagnosis and control of plant microbial diseases, abiotic environmental injuries and disorders, animal pests and weeds.

The proposed definition of plant medicine as a theoretical and practical branch reflects the unity of science (research and synthesis of knowledge into principles and generalisation) and plant health care due to prevent and direct treatments. Such a conception of plant medicine can be useful for creation or re-creation of balance between theoretical and practically oriented activities in the field of plant health. They must be done both concurrently and in balance. But, as a matter of principle, plant medicine must maintain an agriculture and forestry orientation. Besides agriculturists and foresters, the branch of plant medicine must be accepted by local, regional and world society. However, undoubtedly there are times when different names with different connotation fit both the recent condition of knowledge and the temporary political climate more advantageously (Snyder 1971).

2.2 Absence of consensus in plant health and plant disease concepts

2.2.1 Conceptualisation of plant health and disease

Different approaches to the concept of health and disease may be found in the literature dealing with plant pathology (Federation of British Plant Pathologists 1973) and veterinary medicine (Gunnarsson 2006). These approaches take into account the following aspects: (*i*) health as normality and disease as abnormality; (*ii*) health linked to a biological functioning; (*iii*) disease as a structural or functional alteration in the cells of which all living entities are made (which is the common idea within pathology); (*iv*) health as a condition of delicate dynamic functional balance within the organisms or within the processes in the organism (homeostasis); (*v*) disease as a disturbing of the normal interplay of organism functions; (*vi*) disease as a failure to produce at the expected level of nutritional supply and environmental quality.

In the sense of the above-mentioned criteria, plant health can be defined as relative freedom from biotic and abiotic stresses that limit plant productivity both in quantity and quality from its

genetic potential (Chaube & Singh 1991; Browning 1998). The definition of plant health as a mirror image of plant disease emphasising the positive aspect (health) as opposed to the negative one (Tammen & Wood 1977) seems to be naïve and can be considered as a dichotomous definition (Gunnarsson 2006).

2.2.2 The abandonment of Kühn's initial conception of plant disease

In 1858, Julius Kühn, regarded as the father of modern plant pathology, published the textbook called in German *Die Krankheiten der Kulturgewächse, ihre Ursachen und ihre Verhütung* (The Diseases of Cultivated Plants, their Causes und their Prevention). Here for the first time in a phytopathological text, the fundamental facts about the causal nature of fungi as pathogens in the diseases of plants were coherently adopted. With a fine grasp of the entire field of etiologic phytopathology, Kühn, while recognizing a new pathogenic factor, fungi, did not deny the old and generally accepted factors of weather, soil conditions, animals (!), and parasitic flowering plants as producers of diseases. He accepted them, but gave them their proper place and value in his treatment of the subject (Whetzel 1918; Wilhelm & Tietz 1978).

Specialisation is the most distinctive characteristic of modern science and a major impetus was observed in the 20th century. Plant pathology, not established as a branch of science until the second part of 19th century, developed later in two separate branches, namely plant pathology on the one hand and animal pests (as a special part of applied zoology) on the other hand. As Cowling and Horsfall (1979) stated "this pattern of declustering biologists has inhibited interaction between pathologists and entomologists [and other zoologists] for decades".

In some countries, the term plant pathology covers (or covered in the past) all diseases and disorders of plants including attacks by insects and other pests of animal origin. According to McCallan (1969), an organic union of plant pathology and pathological entomology is the most logical especially from the applied and extension point of view. He also noted that it was doubtful whether the organic union would ever come about in the USA, especially since there were about twice as many entomologists as there were plant pathologists. Plant pathologists would be outvoted. Moreover, in the 1920's, the role of insects was considered as almost entirely mechanical rather than disease provoking. The growing importance of entomology and the need for a closer integration of entomology with the discipline of plant pathology have become much clearer after the recognition of the role played by insects in the transmission of infective principle in the cases of viruses, pathogenic fungi and bacteria (Muskett 1967).

In plant health science or in plant medicine, the current concept of disease was primarily tailor-made by plant pathologists (American Phytopathological Society 1940; British Mycological Society 1950; Federation of British Plant Pathologists 1973). In the concept of American and British plant pathologists, injuries to plants caused by animals are not classed as disease together within those caused by pathogenic organisms or viruses. However, that seems to be an odd attitude which does not respect the concept of disease in human and veterinary medicines. In these two branches of medicine, disease is a term used infrequently for any condition that impairs the normal functioning of human and animal organisms. In human and veterinary medicines ectoparasites of animal origin, i.e. animals that live parasitically on the surface of another animal's or human's body, are regarded as causal agents of some diseases. For example, scabies or itch mite (*Sarcoptes scabiei*) causes a disease that attacks the skin of humans, domestic and wild mammals (Pence & Ueckermann 2002).

Of nematodes, many parasitic forms cause diseases in most plants, animals and humans

In short, it can be said that what is and what is not a disease is a matter of complex decisions using sharp criteria and ultimately an arbitrary designation (King 1954).

2.2.3 Polyfunctional role of animal pests in plant malfunctions

The disease concept is the cornerstone of the science of plant pathology (Horsfall & Cowling 1980). Of animal pests, parasitic phytonematodes may cause diseases or may be involved in the production of diseases (Dropkin 1979). Norris (1979), and before him Miles (1968), considered insects, mites and perhaps other animals as inducers not just of injury, but of disease in plants. However, most plant pathologists and entomologists express a tendency to underestimate the role

of some animals in the induction of plants diseases. Besides, the role of plant-sucking insects as vectors of viruses as well as mites should not be overlooked (Leach 1940; Carter 1973; Wallace 1978).

After the analysis of mechanisms by which plant health is disturbed by animal organisms (Table 1), we came to the conclusion that animals can be regarded as follows: (*i*) causal agents of infectious diseases (i.e. endoparasitic nematodes and protozoa); (*ii*) non-infectious diseases (i.e. ectoparasitic nematodes, some sap-sucking arthropods such as aphids, whiteflies, scales, mealybugs, leafhoppers and thrips): (*iii*) or biotic injuries (i.e. chewing insects, borers, molluscs, mammals and birds).

2.3.4 Disease versus disorder

To the present day, abiotic environmental factors that cause plant health problems have been a part of the study of plant pathology. However, a great many contemporary plant pathologists take little interest in abiotic factors as causes of plant malfunctions. They are mainly focused on infectious diseases and some of them even feel that the abiotic plant health problems should be handled by agronomists, horticulturists or foresters. But on the other hand, plant pathologists also realise that they encounter many problems of abiotic origin and must be able to identify them, if not for other reason than to eliminate abiotic causes. And of course, the identification of major classes of abiotic malfunctions of plants should certainly be part of the training of all plant pathology students at the undergraduate and graduate level.

In compliance with American Phytopathological Society (1940) (thereinafter APS 1940), disease is a deviation from the normal functioning of physiological processes, of sufficient duration to cause disturbance or cessation of vital activity. Analogically, British Mycological Society (1950)

Table 1. Characterisation of animals as causal agents of diseases and injuries

Characteristic of causal agent (CA), pathological and epidemiological classification of plant health malfunction	Taxonomical group of causal agent	Animals	
		as CA of disease	as injury inducers
CA (causal agent) affects plant by puncturing plant organs, removing sap or cell content and inducing cellular dysfunction	**sap sacking arthropods**: aphids; whiteflies; scales mealybugs; leafhoppers	+	–
CA rasps the surface of plant tissue and suck the plant sap	**thrips**	+?	–?
CA injures plants by injecting salivary fluids (containing toxic, enzymatic or growth substances) and induces the formation of galls	gal mites; gall aphids; pod gall midges	+	–
CA eats (chews) plant tissue and cause damage symptoms such as clear eating, leaf notching , shot-holing, skeletisation or mining	**chewing insects**: beetle adults; or larvae; moth larvae (caterpillars); many other groups of insects	–	+
CA burrows into wood of tree and shrubs and interrupts the flow of water and nutrients through the conductive tissue	**borers (woodboring beetles)**	–	+
CA feeds leaves and tender stems and its presence is noticeable by its track silver slobber	**mollusc**s	–	+
CA rubs or frays the bark of small trees	dears	–	+
CA causes bark stripping on trees usually in winter	dears	–	+
CA gnaws at tree stems and roots	rodents	–	+
CA browses of young herbaceous shoots of seedlings	hamsters	–	+
CA breaks stems and shoots	red dear or moose	–	+
CA grazes herbs down to ground level	ruminant species	–	+
CA creates a subterranean pasts in the ground and damage roots	European squirrels	–	+
Flocks of CAs (birds) consume or damage seeds and fruits	birds	–	+

+ characteristic is present; – characteristic is absent; +/– characteristic is present or absent

(thereinafter BMS 1950) defined disease as a harmful deviation from the normal functioning of physiological processes.

More than 20 years later, Federation of British Plant Pathologists (1973) (thereinafter FBPP 1973) in *A Guide to the use of terms in plant pathology* noted that APS and BMS definitions were broad enough to allow malfunctions caused by nutritional deficiencies or excesses, toxic chemicals, adverse environmental factors, genetic anomalies, etc. to be classed as diseases in addition to those caused by *infective* agents.

In compliance with the APS conception, Agrios (2005) defined disease as any malfunctioning of host cells and tissues that results from continuous irritation by a pathogenic agent or environmental factor and leads to development of symptoms. In opposition to APS and Agrios's definitions, the FBPP conception distinguished between disease and disorder. FBPP (1973) recommended that the term *disease* should be applied only to malfunctions caused by *pathogenic* organisms or viruses, and that those caused by other factors should be termed *disorders*. According to FBPP (1973), disorder was defined as a harmful deviation from the normal functioning of physiological processes, arising from causes other than pathogenic organisms or viruses, e.g. mineral deficiency or toxicity, genetic anomaly, low-temperature injury, etc.

To sum up, while APS and BMS definitions of disease comprise plant health problems caused by both biotic and abiotic agents, the FBPP definition, on the other hand, does not consider the abiotic agent as a cause of plant disease.

One can assume that confusion established by the above-mentioned definitions is untenable in future on good grounds:

– Both APS (1949) and BMS (1950) definitions of disease may be interpreted as disregarding the crucial differences between plant health problems caused by biotic and abiotic causal agents.
– **Agrios's definition of disease appeared as** misguided saying that **any** malfunctioning of host cell and tissues resulting from **continuous irritation by** a pathogenic agent or environmental factor can be assumed as disease.
– The definition of disorder suggested by FBPP (1973) can be regarded as challenging because it expressed the need to select and introduce into practice a suitable name for plant health malfunctions attributed to abiotic factors as an opposite to infectious disease. However, the name ***disorder*** itself does not seem to be suitable for the characterisation of all categories of existing plant malfunctions of abiotic origin. For example, frost injury, hail injury or herbicide injury, etc. can hardly be considered as disorder according to the FBPP definition. As will emerge from the text below, the terms disorder and injury are separate names which should have the equal rank in a hierarchical structure of names used for plant health malfunctions.

2.3.5 Injury versus damage

In accordance with Nutter *et al.* (1991), **injury** is visible or measurable symptoms and/or signs caused by a pathogen or pest. On the other hand, **damage** is any reduction in the quantity and/or quality of yield that results from injury. However, in some technical texts published for example in Disease Compendium Series of the American Phytopathological Society, injury and damage terms are used synonymously and Agrios (2005) defined injury as damage of plant by animal, physical, or chemical agent.

2.3.6 Ambivalence in the use of names for plant malfunctions of abiotic origin

It could be expected that American plant pathologists will follow APS or Agrios's concept of disease in their publications (see the paragraph "Disease versus disorder" above). To verify this presumption, we have analysed 30 Disease Compendia issued in 1976–2006 by APS to find out an absolute and relative frequency of various names for plant malfunctions of abiotic origin (Table 2).

Of the 30 analysed Disease Compendia of diverse crop plants, 14 different names were used for the same types of plant health problems of abiotic origin (Table 2). The used names were two-word to six-word ones. The term *disease* was a component of names eighteen times, the term disorder eleven times and the term *condition* only once. The most frequent compound lexemes were *noninfectious disease* (in 33% crops) and *noninfectious disorder* (in 26% crops). These results clearly document considerable disunity in the use of two main categories of plant health malfunctions among authors of Disease Compendia of APS during the last 30 years.

In Diseases Compendia of APS we can encounter not only such compound names as *noninfectious*

Table 2. Frequency of various names for plant malfunctions of abiotic origin used in disease compendia issued by American Phytopathological Society

Name	Crop plant	Absolute frequency	Frequency of term		
			disease	disorder	other
1. abiotic **diseases**	conifers, elm	2	2		
2. abiotic and physiological* **disorders**	pepper	1		1	
3. abiotic **disorders**	beet	1		1	
4**. diseases** caused by abiotic agents	alfalfa, raspberry and blackberry	2	2		
5. **diseases** in absence of infectious pathogens	potato	1	1		
6. **diseases** caused by noninfectious agents	rhododendron and azalea	1	1		
7**. disorders** caused by abiotic factors	grape, tropical fruit	2			
8. abiotic **diseases**	lettuce, umbellifers	2	2		
9. noninfectious abiotic **conditions**	onion and garlic	1			1
10. noninfectious **diseases**	wheat, barley, turfgrass, pea, tomato, rose; ornamental foliage plants, flowering potted plants	8	8		
11. noninfectious **disorders**	cucurbit, apple and pear, stone fruit, blueberry and cranberry, nut crop; chrysanthemum	6		6	
12. noninfectious **disorders caused by genetic and environmental factors**	strawberry	1		1	
13. noninfectious or abiotic **diseases**	corn, tobacco	2	2		
14. noninfectious or stress **disorders**	soybean	1		1	
Frequency of term	absolute frequency	30	18	11	1
	relative frequency (%)	100	60	37	3

*According to Schutzki and Gregg (2007) the term "physiological disorders" reflects the fact that the injury or symptom we see, such as reduced growth or crown dieback of tree, is ultimately due to the cumulative effects of the causal factors on the physiological processes needed for plant a growth and development

disease but also *noninfectious disorder*. It clearly demonstrates that American plant pathologists reject the definition of disorder submitted by the Federation of British Plant Pathologists (FBPP 1973). From the point of view of the FBPP conception the term *noninfectious disorder* can be regarded as a semantic pleonasm.

3 A proposal for solving some terminological problems

3.1 Categorization of plant health malfunctions

Plant diseases, like human or animal diseases, may be categorised in several ways. Usually, they are classified by cause (aetiology), by the mechanism causing the disease (pathogenesis mechanism) or by symptom(s). Alternatively, plant diseases may be classified according to the plant species (host plants) or group of plant species affected, though many diseases affect more than one plant species or organ (such as root, stem, leaf, or part of flower).

In this article, the following criteria were used for the classification of a wide spectrum of plant health malfunctions: origin of causal agent, the mechanism by which the causal agent disrupts plant health, and epidemiological features. The results are presented in Tables 3–6. After the analysis of common and different properties of particular plant health problems and relationships between them, we can follow their categorisation.

Table 3. Classification of plant health malfunctions

Characteristics of causative agent (CA), pathological and epidemiological classification of plant health malfunction		Categories of plant health malfunctions PLANT DISEASE (in a broad sense)							
		Endogenic disease (genetic disease)	Exogenic disease						
			BIOTICOSIS			ABIOTICOSIS			CO-ABIO-BIOTICOSIS
			disease (in a strict sense)		injury	disorder			
			infectious	non-infectious	biotic	abiotic	nutritional	environmental	
A. Origin of CA	• biotic (living) entity	**+?**	+	+	+	–	–	–	–
	• abiotic (non-living) entity	–	–	–	–	+	+	+	–
	• complex of abiotic and biotic entities or conditions	–	–	–	–	–	–	–	+
B. Characterization of CA – plant interactions	• **continuous** irritation of plants due to: – infective CA	–	+	–	–	–	–	–	–
	• **continuous** irritation of plants due to: – noninfective CA	–	–	+	–	–	–	–	–
	• **sustained** disruption of plant due to presence (infestation) of animal CA on or in the plant – an instantaneous or transient irritation of plant due to:	–	–	+	–	–	–	–	–
	• **sustained** disruption of plant due to presence (infestation) of animal CA on or in the plant – animal CA	–	–	–	+	–	–	–	–
	• **sustained** disruption of plant due to presence (infestation) of animal CA on or in the plant – abiotic CA	–	–	–	–	+	–	–	–
	• harmful deviation from plant health due to: – hereditary condition	+	–	–	–	–	–	–	–
	• harmful deviation from plant health due to: – long-running – unfavourable nutritional – environmental conditions	–	–	–	–	–	+	+	–
	• multipathogen attacks involving a primary pathogen and one or more ancillary agents	–	–	–	–	–	–	–	+
	• allelopathic chemicals produced by one plant species are detrimental to other plant	–	–	–	–	–	–	–	+
	• man-made plant health problems caused by improper cultural practices	–	–	–	–	+	+–	+	+
C. CA expresses some level of host specificity		+	+	+	+	–	–	–	–
D. An increase of CA in the number or the concentration during pathological process		–	+	–/+	–/+	–	–	–	+/–
E. Transmissibility of CA from affected to healthy plants		–	+	–	–	–	–	–	+/–

+ characteristic is present; – characteristic is absent; +/– characteristic is present or absent

All plant health problems can be ranked at five levels of the relative position in a hierarchy of the complex of plant health malfunctions, namely: (*i*) **superior category** (plant disease in a broad sense); (*ii*) **group** (endogenic or intrinsic disease, exogenic or extrinsic disease); (*iii*) **class** (bioticosis, abioticosis and co-abio-bioticosis); (*iv*) **type** (infectious disease; noninfectious disease; biotic injury, abiotic injury, disorder), and (*v*) **species (**this rank is earmarked for the naming of a particular plant health malfunction in a particular crop, as for example "hail injury of maize".

3.2 Naming and redefinitions of the main types of plant health problems

The definitions of main categories of plant health malfunctions can be compiled as follows:

Malfunction (syn. *dysfunction*): a failure to function normally (http://www.thefreedictionary.com/malfunction – accessed 2011-01-21).

Disease in a broad sense: any harmful deviation from the normal functioning and structure of plant organism resulting from endogenous and exogenous causes, such as genetic defects,

Table 4. Characterisation of disease in a strict sense

Characteristic of causative agent (CA), pathological and epidemiological classification of plant health problem	Taxonomical group of causal agent						
	viruses viroids	proka-ryote	fungi and fungal-like organisms	seed plants, algae, protozoa	nema-todes	mites	insect
A. Origin of CA							
• biotic (living) agent	+	+	+	+	+	+	+
• abiotic (non-living) agent	–	–	–	–	–	–	–
B. The mechanism by which CA disrupts plant health							
Microbial parasitic pathogenism • CA is capable: – of penetrating **into host tissues** and reproducing within its host; – of living **on the surface** of its host plant, sending haustoria to adjacent host tissue and reproducing on the surface of its host.	+	+	+	–	–	–	–
Microbial nonparasitic pathogenism • CA lives outside the plant and induces disease by secreting toxic substances which are absorbed by plant	–	+	–	–	–	–	–
Parasitism of seed plants • CA sends haustoria to adjacent host plant and stimulates wasteful respiration and transpiration, inhibits photosynthesis, alter growth processes, and become metabolic sinks for host nutrients	–	–	–	+	–	–	–
Parasitism of green algae • CA invades host plant and induces yellowing and dividing of invaded host tissue	–	–	–	+	–	–	–
Parasitism of the flagellated protozoa • CA survive and multiply in the phloem elements of their host plants	–	–	–	+	–	–	–
Endoparasitism (pathogenism) and exoparasitism of nematodes • CA feeds on surface cells or migrate within plant host tissues and may be the pathogen	–	–	–	–	+	–	–
Exoparasitism of sap sacking arthopods	–	–	–	–	–	+	+
C. Pathological and epidemiological features							
• Plant tissues directly affected by CA normally show gradual changes from healthy to diseased condition	+	+	+	+	+	+	+
• CA increases in the number over time as a direct result of its growth and multiplication inside or on host plant	+	+	+	+	+	+	+
• CA expresses some level of host specificity	+	+	+	+	+	+	+
• CA spreads from diseased or infested to healthy susceptible host plants	+	+	+	+	+	+	+

+ characteristic is present; – characteristic is absent; +/– characteristic is present or absent

environmental biotic and abiotic agents and characterised by an identifiable group of signs or symptoms.

Endogenous disease: inborn error of plant metabolism that is passed down from generation to generation.

Exogenous disease: malfunction of plant caused by environmental biotic or abiotic agents.

Bioticosis: malfunction of plant caused by a biotic agent.

Abioticosis: malfunction of plant caused by an abiotic injury or disorder.

Table 5. Characterisation of injury

Characteristic of causal agent (CA), pathological and epidemiological classification of plant health problem	Group of causal agents			
	ABIOTIC			BIOTIC
	external mechanical forces	external physical and chemical phenomena		animal pest of plants (insects, molluscs, mammals, birds)
		in the atmosphere or in soil	chemicals applied to plants wrongly	
A. Characteristics of plant-causal agent interactions				
CA disrupts plant health by contact or attack of plant tissue. This attack may be: momentary (**M**) or short running **(SR**)	M	M	M, SR	SR
Ill-effect of CA manifest itself in plant a short time (very suddenly) after contact with plant (**ST**) or after shorter delay **(SD)**	ST	ST, SD	ST, SD	SD
CA persists and increases in concentration or in the number inside or on the plant	–	–	–	–/+
CA is transmissible from injured to healthy plants	–	–	–	+
Symptoms which result from the attack of CA depends: – on the severity, duration and rate at which CA is acting; – on the feature of the plant, including organ or tissue identity and developmental stage	+	+	+	+
B. Mechanisms by which CA disturbs/disrupts plant health				
CA is an **external mechanical force** that breaks, cracks, scratches, squeezes or compresses a plant by physical contact. This contact may be momentary or lasting longer	+	–	–	–
CA does harm or produce injury to living plants by a foreign poisonous **chemical substance(s)** which can be categorised as being: – environmental (when chemicals occurs in the atmosphere, in the soil or in the water and acts momentarily or for a short time); – or agricultural (when agricultural chemicals are applied to plants or to the soil in the wrong dosage, wrong time or during hot parts of the day)	–	+	+	–
CA adversely affects plant health by the extreme **atmospheric** or **soil conditions,** namely: – by the duration of specific meteorological entity (temperature, precipitation etc.) or weather (drought, humidity, etc.); – by the intensity of the atmospheric phenomena (high or low temperatures, excessive or insufficient light, high wind, driving rainstorm, strong icing, etc.); – by the occurrence of extreme atmospheric conditions in the unusual time (late spring freeze, early autumn freeze); – by direct sun exposure or just by simply too hot air; – cold, freeze, hot, dry windy weather; – by extreme temperature fluctuations especially during winter (periods of warm/cold/warm/cold)	–	+	+	–
CA adversely affects plant products by unfavourable storage conditions		+	+	

+ characteristic is present; – characteristic is absent; +/– characteristic is present or absent

Co-abio-bioticosis: malfunction of plant that results from an interacting set of biotic and abiotic factors.

Disease in a strict sense: malfunction of plant arising from a continuous irritation of either biotic infective or non-infective agents.

Injury: malfunction of plant arising mostly suddenly from an instantaneous or a short-lasting action of abiotic factor or biotic non-infective agents.

Disorder: systemic malfunction of plant caused by long-running nutritional imbalance or long-running unfavourable weather and soil conditions.

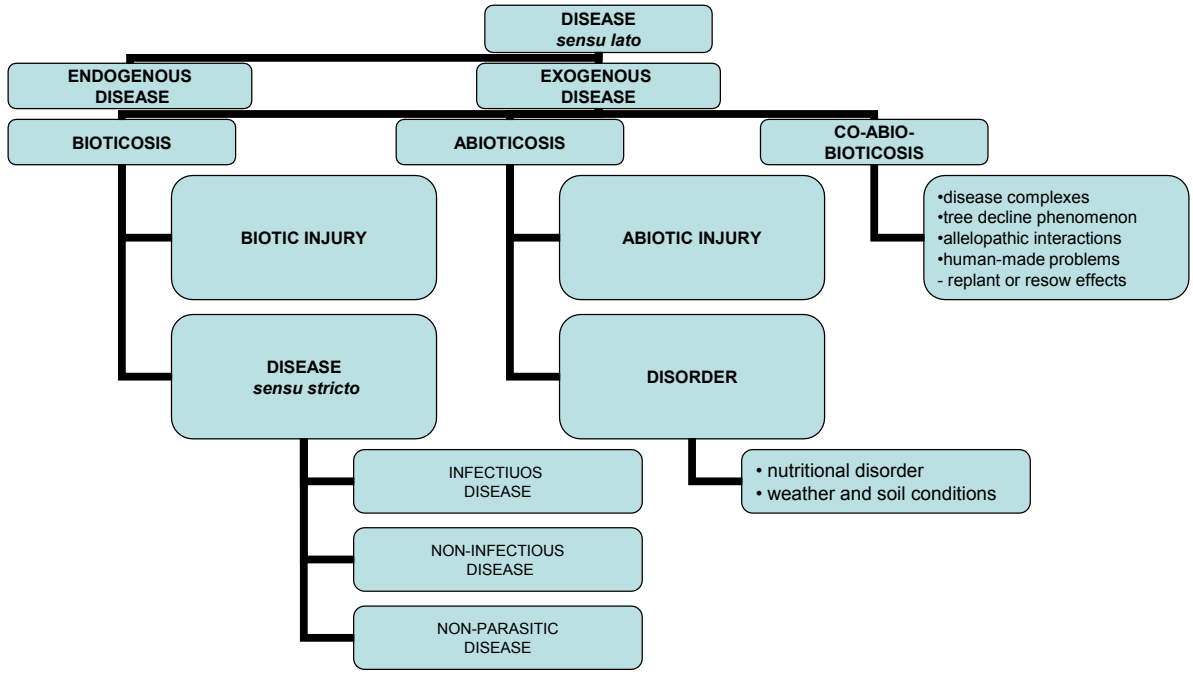

Figure 1. Categorisation of plant malfunctions

The hierarchisation of plant health malfunctions is apparent from Figure 1.

3.2.1 Disease in a broad sense

The concept of plant *disease in a broad sense* includes any malfunction in the growth of the healthy productive plant. The cause(s) of disease thus become broader in concept, which permits thinking and exploring into any facet that may be involved in the disease, and thus encourages investigation over a broad field. But on the other hand, a more restricted concentration on the disease and on the diseased plant in terms of finite plant pathogens such as viruses, bacteria and fungi, tends to limit the scope of thinking and willingness to study and solve the problem (Hewitt 1979). The term *disease in a broad sense*, if accepted, would provide a connecting link among plant pathology, applied entomology and other disciplines of plant medicine. In the past, Stakman (1964) and Grogan (1987) pleaded for a broader concept of plant disease in the sense of Kühn's original conception (see 2.2.2).

3.2.2 Proposed neologisms: bioticosis, abioticosis and co-abio-abioticosis

Factors which can cause plant health problems can be divided into two groups named on whether they are living or non-living. These two groups of names are: disease versus disorder (see above); biosis versus abiosis; and bionosis versus abionosis. However, the terms abionosis and bionosis (from Greak *bios* = life; *abios* = non-life; *nosos* = disease; *-osis* = diseased state caused by) are not acceptable for linguistic reasons. The reason is that word-formative procedures in the cases of the words *bionosis* and *abionosis* can be characterised as blending. These words cannot be acceptable because the affix *-osis* expresses *per se* (i.e. without the word *nosos*) that they concern a pathological event. In spite of this, such term as *bionosis*, defined as any infection or disease caused by living organism, can be exceptionally registered in human medicine literature (Pei-Show Juo 2001).

Being aware of the usefulness of one-word, unambiguous and linguistically accurate substantives for the naming of three groups of plant health malfunctions belonging to disease in a broad sense, we suggest that such requirements could be met by introducing neologisms such as **bioticosis** (Gr. *bioticos* = living; *osis* = diseased state caused by), **abioticosis** (Gr. a = non, *bioticos* = living), and **co-abio-bioticosis (co** = *prefix* together with, jointly) into current terminology. Most of the plant disease complexes including allelopathic interactions and some man-made plant health problems can be incorporated in the category of co-abio-bioticosis (Figure 1 and Table 3).

3.2.3 Disorder and injury

The name *disorder* belongs to controversial terms in plant pathology. Sometimes it is confused with disease (see the paragraph "disease *versus* disorder") and at the other time with injury.

In our approach, all disorders belong to the group abioticosis, whereas injuries fall either in abioticosis or bioticosis. Disorder is a systemic malfunction caused by long-running nutritional imbalance or long-running unfavourable weather and soil conditions (e.g. cold, drought, humidity, acidity, alkalinity, salinity, etc.) and a systemic malfunction is one that affects the plant organism as a whole. But on the other hand, injury is a non-systemic malfunction arising mostly suddenly from an instantaneous or a short-lasting action of causal agent (e.g. frost, hail, pesticide, etc.). However, it must be admitted that criteria such as "long-running" or "short-lasting" action of causal agent may carry the same implication. For example, a malfunction caused by low temperatures can be interpreted arbitrarily either as cold disorder or cold injury.

3.2.4 Disease complexes

In natural settings, it is not uncommon for plants to be affected by: (*i*) simultaneous or mixed infection with more than one virus, a combination of virus with other microbial pathogens; (*ii*) combination of both abiotic and biotic agents.

Composite nature of certain potato viruses. Complexes of viruses are not uncommon as causes of plant disease (Markham 1977). In potato, for example, a severe mosaic leading to "crinkle," "rugose mosaic," or necrosis of leaves may develop by synergistic action of three viruses, *Potato virus* X, in mixed infection with *Potato virus* A (PVA) or *Potato virus* X (PVX). This case represents a situation when it is very difficult to find a proper common name for diseases with complex aetiology.

Table 6. Characterisation of disorder

Characteristic of causal agent (CA), pathological and epidemiological classification of plant health problem	Group of causal agent	
	nutritional conditions	weather and soil conditions
A. Origin of CA		
• abiotic	+	+
B. Characterisitics of interactions plant-abiotic agents		
CA adversely affect plant health by		
• non-balanced nutrition, i.e., by lack or excess of nutrients. Excess of minerals can damage plants either directly or indirectly by interfering with the absorption and use of other nutrients, resulting in subsequent deficiency symptoms	+	+
• internal pressure which exceeds the tensile strength of the surface tissues during fruit or tuber enlargement and initiates physical cracking of the surface tissues. These cracks (so called growth cracks) occur when heavy rainfall occurs after an extended period of dry weather conditions	–	+
• poor weather conditions such as very cold but not freezing temperature for sustained period	–	+
• the poor or extreme **edaphic conditions acting for a longer time**, such as:: – rock content and pH (acidity alkality); – soil type and texture; – soil compaction; – soil pollutants; – excessive concentration of soluble salts in the soil (salinity; – soil temperature extreme (freezing or too hot soil); – soil moisture extremes (drought, wet, waterlogging, flooding); – lack of oxygen generally associated with high soil moisture or high temperature	–	+
C. Pathological features		
CA adversely affects plant for prolonged period	+	+
CA can not be transmitted from one plant to another	–	–

+ characteristic is present; – characteristic is absent; +/– characteristic is present or absent

Complexes of abiotic and biotic factors. According to McGawley and Overstreet (2001), thousands of disease complexes have been described involving almost every conceivable combination of two or more pathogenic agents and it is often difficult to determine which came first. Most disease complexes usually involve a primary pathogen and one or more ancillary agents. In many cases, plants which are initially stressed by abiotic factors will be weakened and therefore predisposed to biotic problems.

Such disease complexes can be caused by a wide array of infectious (biologic/living) agents including nematodes, fungi, viruses, higher plants, mollicutes, protozoa, and insects as well as by non-infectious (abiotic/nonliving) agents such as toxins in the air and water or by excesses or deficits of essential soil nutrients. In the vast majority of plant disease complexes, nematodes are involved in some way, e.g. nematode-fungal complexes, nematode-bacterium complexes, nematode-virus complexes, and nematode-nematode complexes (McGawley & Overstreet 2001).

Disease complexes or diseases of complex aetiology may be sequential or concomitant (Wallace 1978). Sequential disease complexes are those in which one component of the pathogen complex (the "primary" pathogen) infects and alters the host in advance of subsequent invasion by other ("secondary") pathogen component(s). Concomitant disease complexes occur when two (or perhaps more) pathogens infect the host simultaneously (Powel 1979).

In plant pathology, complexes of abiotic and biotic factors are not infrequently omitted by some plant pathologists as a separate type of plant health problems. These interactions of both long-term and short-term factors were studied in particular by forest pathologists (Hepting & Cowling 1977). Manion (1981), a forest plant pathologist, recognised the third type of plant disease, called "decline", which does not result from a single causal agent but from an interacting set of factors. However, not everyone likes to use the decline concept, because: (*i*) it is often a mask for ignorance of diseases and their causes; (*ii*) it may lump a number of unrelated problems under one name making it much more difficult to understand the causes (Worall 2007).

3.2.5 Man-made diseases

Man-made disease is the term that was introduced in the plant pathological terminology by Yarwood (1970) for an accidental result of man's activities or for cultural practices and various other activities necessary or desirable for highly productive agriculture, however, when done incorrectly or improperly timed, they result in higher incidence and development of plant diseases.

Iatrogenic disease of a crop is a disease that is induced or worsened by plant pathologist's prescription of pesticide for that crop. Chemicals can exacerbate a biotic disease when they convert resistance of the host plant, increase the inoculum potential of a pathogen or alter the microclimate to favour disease development (Horsfall 1979). Much more important are situations which arise from disturbing nontarget effects of agrochemicals on the crop ecosystem (Griffiths 1981).

The role of man in agriculture and forestry in relation to plant health is pervasive for its enduring direct or indirect impact on all constituents of ecosystems and can hardly be comparable with the role of exopathogens, exoparasites, pests or agents that predispose plants to a higher or lower attack by pathogens. In other words, the idea of *plant man-made disease* is not well-founded and should not be part and parcel of the official plant health terminology.

3.3 Common names for plant health problems of abiotic origin

In contrast to the basically homogeneous nomenclature of bacterial and fungal diseases, different names are used in abiotic malfunctions with varying frequency. The conventions for naming abiotic plant health problems have developed inconsistently. Therefore, the development of standards for naming abiotic plant health problems becomes important.

Similarly like in the case of infectious diseases, common names of abiotic disorders and abiotic injuries should consist of three components: (*i*) handy expression indicating the nature of the causal agent; (*ii*) prominent symptom; (*iii*) and plant species attacked.

Sometimes it is difficult to find a suitable expression characterising the symptom of malformation. In these cases, a common term such as disorder or injury instead of a concrete symptom may be used. Further particulars about the proposed common names for plant malfunctions caused by abiotic agents are evident from Table 7.

Table 7. Examples of proposed common names for plant malfunctions caused by abiotic agents

Types of malfunction	Version of proposed name	Name used in the Plant Compendia of APS	
		Version	insufficiency of naming: ●; ▲; ◆
Genetic disease	genetic gold fleck of tomato	tomato gold fleck	●
Nutritional disorder	zinc deficient little leaf of apple	apple little leaf	●
	ammonium excess wilt and stunting of lettuce (NH_3 – excess wilt and stunting of lettuce)	lettuce excess of ammonium	▲
	manganese toxic marginal leaf chlorosis of lettuce (Mn-toxic leaf marginal chlorosis of lettuce)	lettuce manganese toxicity	▲
Environmental disorder	soil acid leaf marginal yellowing and browning of grape	"*Sauerschäden*" of grape	▲
	soil salinity leaf burn of strawberry	soil salinity	▲; ◆
		strawberry leaf burn	●
	oxygen deficient blackheart of potato	potato blackheart	●
Abiotic injury	ozon leaf chlorosis of barley	barley ozon injury	▲
	chilling chlorosis and necrosis of cucumber	cucumber chilling injury	▲
	frost crack of apple	apple frost crack	NO
	late frost blossom necrosis of apricot	apricot late frost blossom necrosis	NO
	heat canker of soya	soya canker	●
	sunscald of pepper	pepper sun scald	NO
	drought injury of strawberry	strawberry drought damage	*injury* should be preferred over *damage*
	soil hydro-excessive wilt of tomato	pepper water wilt	▲
	wind lodging of barley	barley wind damage (lodging)	▲
	hail injury of apple	apple hail injury	NO
	lightning injury of potato	potato lightning injury	NO
	growth cracks of tomato	tomato growth cracks	NO
	soil compaction forked roots of carrot	carrot forked roots	●

● = absence of expression indicating the nature of the causal agent; ▲ = absence of expression indicating the prominent symptom; ◆ = absence of the plant name attacked; NO = no criticism

4 CONCLUSIONS

How many times we have read sentences like this: For the purpose of this review/article, the term plant pathology is used to mean all attempts to describe or understand the nature of any deviation from good plant health (referred to as disease or disorder), but excludes damage/injury caused by animals. It is said that plant pathology is for plants largely what medicine is for humans and veterinary medicine for animals. So, there arises a question why plant pathology has not commonly been regarded by the general public until recent days as one of the three medicine branches together with human and veterinary medicines. Among others, one of the reasons might be that plant pathology cannot be considered as a synonym for plant medicine.

Since the second half of the 19th century, the concern about plant health malfunctions has developed in three more or less separate theoretic/practical disciplines dealing with microbial plant pathogens (plant pathology), weeds (weed science) (established on the basis of botany) and animal pests (established on the basis of zoology), including control of diseases, pests and weeds. This form of separation in the plant health branch has matched up to the trend of specialisation as a distinctive characteristic of modern science. On the other hand, such fragmentation inhibited interaction between plant pathologists, specialists dealing with animal pests of plants and weed specialists in research and

education. At the same time, such declustering has been an obstacle to the use of holistic plant-health care in the framework of effective institutional systems on the regional, national and international levels which would be comparable with systems in human and veterinary medicines.

The concept of plant medicine, as theoretical/practical branch, creates a more favourable position for surveying the branch of mission-oriented "defender plants" (the term used by Baker 1982) or "plant health defenders".

In this article, the author compiles arguments for the need of revision of current definitions of basic terms for plant malfunction, such as disease, injury, disorder, etc. After the analysis of common and different properties of particular plant health problems and relationships between them, the author suggests revised definitions of some terms and their new categorisation.

Besides, a revised definition of plant medicine is suggested. This definition reflects the unity of science and plant health care due to prevent and direct treatments. Such conception of plant medicine can be useful for creation or re-creation of balance between theoretical and practically oriented activities in the field of plant health.

The objective of the submitted suggestions is to support efforts aimed at conceptual, nomenclatural and institutional unification of plant medicine analogical with veterinary and human medicines.

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