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OPINION PIECE

The "One Health" concept, and preservation of plant well-being

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Summary. This paper outlines development of the "One health, one medicine" concept, and proposes that plants are given a rightful place in the One Health framework. There are many links between plant health and health of humans and animals, and between plant medicine practices and those for humans and animals. Use of pesticides in agriculture requires that plants are integrated into the One Health framework, because effective plant protection methods are essential for management of diseases, insect infestations, and weed invasions. The ultimate goal of a "plant doctor" is to diagnose and effectively manage health problems in productive and natural plant communities.

Keywords. Plant medicine, plant pathology, pesticides, food safety, food security.

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HUMANS AND PLANTS

Human and pre-human interests in plants date back thousands of years, with utilization of plant fruits, leaves, seeds, bark, and shoots. These practices have continued and increased as *Homo sapiens* evolved and spread across the world.

Beyond food, there are many other reasons for human interest in plants. In addition to production of oxygen essential for respiration, and absorption of carbon dioxide from the air, plants are also essential for purification of soil and water, provision of materials for shelter building, treating diseases, and production of textile fibres and useful pigments. Expansion of botanical knowledge has also provided fundamental knowledge, such as discovery of cells as the building blocks of life which were first observed in plants, Mendel's descriptions of the laws of heredity in plants revealed from study of *Pisum*, and purification of viruses from tobacco plants.

Plants are also expressions of harmony and silent beauty. They shape landscapes, convey emotions, and are increasingly perceived as living beings with "intelligence" and deserving of respect and protection.

These considerations raise the question: how is it possible to conceive of any global system that promotes dialogue between humans and animals but excludes plants? Yet even in medieval times, there was awareness of interconnections between humans, animals, and plants.

An example is a 12th-century miniature (Figure 1), which illustrated a vision of St Hildegard of Bingen (1098–1179). She was a medieval German nun, mystic, poet, linguist, musician, herbalist, naturalist, and healer. She had visions throughout her life, *non in somnis nec in extasi but vigilans corpore et mente*, which were then illustrated in miniatures of exquisite quality. One of these, contained in the *Liber divinorum operum*, details the influence on terrestrial life of the spheres of red fire, black fire, air, and water. In the miniature, the space is divided into four quadrants: in the upper left, the effects are depicted of sparks descending from the red fire to carry out the vengeance desired by God's judgment. Divine punishment is exemplified by the succession of increasingly bare plants and in the transition from a human figure bringing a contaminated fruit to his mouth to another lying dying or lifeless with ulcerated legs. The consequences of those who sin against God are also depicted in the third and fourth quadrants. In particular, in the third quadrant, there is a figure leaning against a tree, holding a hand to his chest as a sign of illness, and nearby is the carcass of a calf attacked by a bird of prey. In the fourth quadrant of the illustration, everything appears to be in balance and in God's grace. The tree is laden with fruit, and two healthy farmers are busy cutting grass and ripe wheat. In Hildegard's vision, the events that take place on the surface of the world are all closely connected.



Figure 1. A 12th-century miniature illustrating one of St Hildegard of Bingen's visions. In Hildegard's vision, the events that take place on the surface of the world are all closely connected. (Hildegard von Bingen <santa>, *Liber divinorum operum*, c. 38r, sec. XIII, Biblioteca Statale di Lucca, Italy, ms. 1942).

"ONE HEALTH": A BALANCED CONCEPT

Increased awareness of the close connections between human health and animal health gained strength and substance in the 19th century. A key figure in this development was Robert Virchow (1821–1902), a German physician, who argued that no fundamental distinction exists between animal and human medicine. The object is different, but "the experience obtained constitutes the basis of all medicine," and it was Virchow who coined the term "zoonosis" to describe diseases transmissible between animals and humans. The Canadian physician William Osler (1849–1919), a student of Virchow in Germany in 1873, was the first to use the term "One Medicine" in English-language literature (Saunders, 1987; Cardiff *et al*., 2008), but always referring to human and veterinary medicine, partly because plant medicine was, at that time, only in its beginnings. Nevertheless, Virchow's and Osler's vision of a unified approach to health laid the intellectual foundations for the modern One Health concept, which seeks to integrate human, animal, environmental, and increasingly, plant health, into a comprehensive framework for addressing complex health challenges.

During the second half of the 20th century, Calvin W. Schwabe of the University of California, Davis, United States of America, reintroduced the "One Medicine" concept in his book *Veterinary Medicine and Human Health* (1964). Subsequent research has demonstrated that many human diseases are caused by zoonotic pathogens, while numerous viruses, bacteria, and protozoan parasites originating from wildlife and domesticated animals can also be transmitted to humans through contaminated food and water. This highlights the numerous interconnections among humans, animals, plants, and the abiotic environment, all of which form components of a complex biological and geophysical network that spans the globe.

In this regard, the Gaia hypothesis, formulated and co-developed by James Lovelock and microbiologist Lynn Margulis, and published in 1979 in *A New Look at Life on Earth*, is truly fascinating. According to this hypothesis, "*living organisms on Earth interact with the surrounding inorganic components to form a complex syn-*

ergistic and self-regulating system that helps maintain and perpetuate the conditions for life on the planet." Although the Loveloch and Margulis hypothesis is debated, what is indubitable is that among living organisms that populate the Earth, plants are a fundamental pillar that supports the complex natural interactions that occur between environments, humans, and animals.

Osler's concept of One Medicine subsequently evolved into the broader concept of One Health, a term that gained prominence during 2003–2004 in response to the emergence of the Severe Acute Respiratory Syndrome (SARS) in early 2003, and was further reinforced by the global spread of highly pathogenic avian influenza H5N1. The outbreaks of these two diseases and others (including Nile Virus, Ebola Hemorrhagic Fever, and Mad Cow Disease) prompted international experts to meet in September 2004, to focus "*on the current and potential movements of diseases among human, domestic animal, and wildlife populations*." This symposium, entitled "One World, One Health," was organized by the Wildlife Conservation Society, and was hosted by The Rockefeller University. An outcome from the symposium was 12 recommendations, known as the "Manhattan Principles," that aimed to create an international and interdisciplinary action plan for health.

There are several definitions of the One Health concept. One that most fully expresses the close connections between human health, environmental quality, and animal and plant life, is the definition shared by the United States of America Centers for Disease Control and Prevention and the One Health Commission. This states that *'One Health is defined as a collaborative, multisectoral, and transdisciplinary approach -working at the local, regional, national, and global levels- with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment'*. This definition, where plants are placed on a par with humans and animals, advocates an interdisciplinary approach to public health, that, to be successful, should engage professionals from the fields of human medicine (physicians), animal medicine (veterinarians), and plant medicine (plant pathologists and agricultural entomologists), working in collaboration with biologists, agronomists, ecologists, sociologists, economists, and other relevant experts. The appeal contained in the Manhattan Principles was taken up by the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the World Organization for Animal Health (WOAH), and the United Nations Environment Programme (UNEP). These organizations, sometimes referred to as the One Health Quadripartite, and their representatives, form the One Health High-Level Expert Panel (OHHLEP). The joint work of these organizations led to the publication of the Joint Action Plan for One Health (OH-JPA) for the period 2022-2026. [The Quadripartite could have been pentapartite if it had also included the International Society for Plant Pathology (ISPP)].

The five-year OH-JAP plan set operational objectives and focused on six areas of intervention, including:

- zoonotic epidemics,
- endemic zoonoses,
- neglected and vector-borne tropical diseases,
- food safety,
- antibiotic resistance, and
- environmental quality.

The plant world, and plant health in particular, has received limited or no consideration within the OH-JAP. At best, plant-related issues have been subsumed under the broad and often ill-defined concept of "environmental quality." However, professionals working in plant health recognize that threats to plant health can have far-reaching consequences for animal welfare, human health, and ecosystem integrity. Plant diseases, pests, and other factors affecting crop productivity can compromise food availability, economic stability, and environmental sustainability. Indeed, healthy crops are a fundamental prerequisite for global food security, underscoring the need to explicitly incorporate plant health into the One Health framework.

FOOD SECURITY AND FOOD SAFETY

The definition of food security adopted at the 1996 World Food Summit, encompasses two closely related but distinct dimensions, reflected in the concepts of "food security" and "food safety". Food security refers to ensuring that all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Food safety, in contrast, concerns the absence of harmful substances, contaminants, or microorganisms in food that may compromise the health of humans and animals. The relative importance of these dimensions varies across regions. In countries where the risk of famine and food shortages is low, concerns are generally focused on the quality, safety, and nutritional value of food. Conversely, in regions where malnutrition and food scarcity remain prevalent, ensuring adequate food quantity is often the primary challenge.

Mycotoxins pose food safety risks to human and animal health. These chemicals include aflatoxins,



Figure 2. A maize cob colonized by a mycotoxigenic species of *Fusarium* (photo courtesy A. Moretti).

ochratoxin A, patulin, trichothecenes (e.g. deoxynivalenol and nivalenol), and the T-2 and HT-2 toxins, zearalenone, fumonisins, which are toxic secondary metabolites produced by particular fungi (mainly species of *Aspergillus, Fusarium,* or *Penicillium*) (Figure 2). These organisms contaminate or parasitize plant species or their products, including cereals, nuts, oilseeds, wine, fruit juices, milk, or meat from animals fed with contaminated feed. Even at low concentrations, mycotoxins can have adverse effects on human and animal health, including gastrointestinal disorders, kidney damage, immunosuppression, reproductive impairment, and carcinogenicity (Figure 3). As a result, mycotoxin contamination is a significant challenge at the interface of plant health, food safety, and public health. Ergotism is a historically significant example of mycotoxicosis and human poisoning, caused by alkaloids produced by *Claviceps purpurea*, the fungal pathogen responsible for ergot of rye. Consumption of rye products contaminated with ergot alkaloids led to outbreaks of "St Anthony's fire", probably the first documented human disease caused by mycotoxins. Symptoms of ergotism included severe vasoconstriction, tissue necrosis leading to limb loss, convulsions, hallucinations, and vomiting. The societal impact of the disease is reflected in historical records and artistic representations, including the 1559 painting *The Fight between Carnival and Lent* by Dutch painter Peter Bruegel (c. 1525/1530 – 1569) (Figure 4), which has been interpreted as depicting some of the characteristic manifestations of ergot alkaloid poisoning, including physical deformities, and limb detachment. The history of ergotism illustrates the profound links between plant diseases, food contamination, and human health, highlighting the importance of plant health management within the broader One Health framework.

Human and animal health risks can also arise from exposure to plant-associated microorganisms, including pathogens that are traditionally considered to infect only plants. A notable recent case is the first reported human infection caused by *Chondrostereum purpureum* (Figure 5), the fungal pathogen responsible for silver leaf in numerous woody plant species, as was reported by Soma and Ray (2023). This case occurred in India, and affected a 60-year-old mycologist who, following the infection, developed a paratracheal abscess, hoarseness, coughing, and swallowing difficulty. The patient was successfully treated with antifungal therapy and drainage of the abscess, and recovered fully after approx. two months. Although such cases appear to be rare, they highlight the potential for plant-associated fungi to cross traditional host boundaries and infect humans under specific circumstances. This case also illustrates the dynamic nature of host–pathogen interactions, and reinforces the interconnectedness of plant, human, and environmental health within the One Health framework. As environmental changes, global trade, and human exposure to diverse microorganisms continue to increase, understanding the potential health implications of plant-associated pathogens becomes increasingly important.



Figure 3. Pigs are considered one of the animal species most sensitive and vulnerable to the dangers of mycotoxins, particularly T-2 toxin, deoxynivalenol, zearalenone, ochratoxin A, and aflatoxins, which are found in contaminated grains and cause serious health problems and economic losses (photo courtesy D. Favaro).



Figure 4. Detail from “The Fight Between Carnival and Lent” (1559), by Pieter Bruegel the Elder. In the centre are scenes thought to depict the effects of ergot alkaloid poisoning: physical deformities, and limb detachment. Kunsthistorisches Museum, Vienna, Austria. Pieter Brueghel the Elder, Public domain, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:The_Fight_Between_Carnival_and_Lent.jpg

PESTICIDES IN AGRICULTURE

Ensuring adequate food supply for the world’s population (approx. 8.3 billion in 2026) is an increasingly complex challenge that depends on multiple interconnected factors. Among these, plant health is of fundamental importance. Plant diseases can substantially reduce crop yields and quality, leading to economic losses for farmers and decreased agricultural productivity. Consequently, poor plant health can undermine food availability and accessibility, thereby hampering efforts to alleviate poverty, improve livelihoods, and achieve global food security.

Protection of plants from diseases caused by viruses and phytopathogenic microorganisms, as well as from insect attacks and weed competition, has relied predominantly on chemical pesticides since the mid-twentieth century. It is universally accepted that one of the main strategies for protecting plants and plant products against harmful organisms, including weeds, and to improve agricultural production, is through the use of plant protection products. More recently, new knowledge has improved practical disease management, including deployment of resistant cultivars and host resistance genes, use of disease forecasting models and decision support systems, application of plant defence elicitors, and exploitation of biological control agents and disease suppressive soils. As a result, management of plant diseases, insect pests and weeds is increasingly based on integrated approaches that combine cultural, physical, biological, and ecological methods to reduce reliance on chemical pesticides while maintaining effective crop protection.

Despite these recently developed strategies, and despite acquisition of new knowledge in plant health research, agricultural production losses due to plant diseases remain substantial, and have increased compared to 50 years ago.

In 1987, based on analyses of data originally collected in 1967 and appropriately amended to account for the elapsed time, it was estimated that global losses due to plant diseases was approx. 12% of potential production, and at 1987 prices, this was equivalent to an annual monetary loss of approx. US$ 90 billion for crop producers. In quantitative terms, plant diseases were estimated to cause losses of approx. 900 mil-



Figure 5. Fruiting bodies of *Chondrostereum purpureum*, the agent of silver leaf of woody hosts, on a chestnut tree. A single case of human infection (paratracheal abscess) with this fungus has recently been reported (photo courtesy Daina Grinbergs Salas).

lion tonnes of agricultural products each year, including about 250 million tonnes of cereals. These figures highlight the persistent and global nature of plant disease threats, and underscore the continuing need for effective and sustainable plant health management strategies. Currently, more than 4 million tonnes of pesticides, with an estimated market value exceeding 100 billion dollars, are used worldwide each year. Herbicides account for approx. 50% of total pesticide use, followed by insecticides (30%) and fungicides (17%). Despite this substantial investment in crop protection, plant diseases continue to cause significant yield losses. Gai and Wang (2024), who cited Oerke (2006) and Savary *et al*. (2019), estimated that the annual world crop yield losses due to plant diseases was more than 30%. Yield losses due to plant diseases and pests have been calculated to average 21.5% for wheat, 30.0% for rice, 22.5% for maize, 17.2% for potato, and 21.4% for soybean. These figures suggest that yield losses in many of the world's most important crops remain persistently high, and may be increasing despite advances in crop protection technologies. Several factors may contribute to this trend, including climate change which is altering pathogen distribution, favouring the emergence of new diseases, and increasing pathogen aggressiveness. Additional contributing factors may include changes in host susceptibility, the declining availability or efficacy of particular plant protection products, and increasingly stringent regulatory restrictions on pesticide use. Together, these challenges highlight the need for innovative, integrated, and sustainable approaches to plant health management.

The European Union has established a rigorous system for management, authorization, and control of plant protection products, that is based on a precautionary and scientific approach. Directive 91/414/EEC of 15 July, 1991 harmonized rules for protection of plant products in European countries, establishing a list of acceptable active ingredients. At that time, application of the Directive led, amongst other things, to the withdrawal of many, then available, active ingredients (Figure 6). Other similarly positive results were achieved with the application of EC Regulation 1107/2009 and EC Directive 128/2009. Directive 128/2009 made Integrated Pest Management (IPM) strategies mandatory, and divided active substances into four risk categories.

Despite these strict measures, in 2019 the European Commission presented a new strategy, the "European Green Deal", which contained, among other objectives, aims to reduce greenhouse gas emissions compared to 1990 levels by 55% by 2030, and to eliminate CO_2 emissions by 2050.

The "Farm to Fork Strategy" is key to the European Green Deal, which aims to make food production systems fair, healthy, and environmentally friendly. Part of this strategy was the Regulation on the Sustainable Use of Pesticides (SUR), first presented in June 2022, which had the ambitious goals of halving pesticide use in the European Union by 2030, and reducing use of so-called hazardous plant protection products on the market by 65%. The Strategy also called for a ban on the use of all chemical pesticides in sensitive areas, including urban green spaces.

Faced with protests from various quarters, the European Commission withdrew the law on chemical pesticides before it was due to come into force. Was this a wise, albeit necessary, decision by the European Commission, or have other interests prevailed, at least for now? It is not important to answer this question, but two facts (possibly contradictory) must be highlighted, unless specific tools and instruments, not yet available, are rapidly developed. Firstly, the severe production loss-



Figure 6. An old package of Dithane® (zineb; zinc ethylenebis-dithiocarbamate), previously considered an efficacious, safe, multipurpose foliar and soil fungicide for control of leaf spots, blights, and fruit rots of vegetables, flowers, fruit trees, and shrubs. This product is now banned by the European commission for its potential risk to cause human thyroid problems and birth defects.

es due to plant pathogen and insect infestations require careful crop protection for prevention. Secondly, future direction is toward reduced pesticide use in agriculture, replaced primarily by biocontrol products [microorganisms; natural inorganic substances (excluding heavy metals and their salts), and substances of biological origin or synthetically produced that are functionally and structurally similar to natural products, according to the Omnibus simplification package published in 2025 by the European Commission].

An important recommendation for this strategy should be that each new biological product must guarantee relevant plant protection capacity at least equivalent of that of the synthetic chemical compound it replaces, so that there is no risk of having well-protected ecosystems that are inhabited by hungry and food insecure humans and animals.

FUTURE CHALLENGES FOR PLANT PATHOLOGISTS

Two key challenges emerge that must be addressed and overcome in future years. These are:

1. rapid development of new means to combat diseases and insect pests, and strategies for their use, before further pesticide use reductions in agriculture/ horticulture are mandated by law; and
2. creation of effective connections between plant medicine with human and veterinary medicine, so that models are developed that protect the health of all living things, ensuring world biological integrity for present and future generations.

Both of these challenges, but particularly the first, should be embraced as core priorities by plant pathologists. Addressing them must be integral to the mission of plant pathology, just as disease prevention and treatment are central objectives in human and veterinary medicine. At its core, the role of the "plant doctor" is to diagnose, prevent, and manage plant health problems, thereby safeguarding crop productivity, food security, and ecosystem resilience. The guiding principle of plant medicine can be summarized as "prevent and treat," reflecting its strong parallels with other health disciplines. This perspective is not new. Nearly seven decades ago, Walker (1957) emphasized the fundamental importance of solving plant disease problems, a view later reinforced by Wellman (1971), who stated that *"All the academic duties, reading, teaching, and research in a plant pathologist's life have one central purpose, and that is to control plant diseases*".

Plant pathologists will continue to be asked – as doctors or vets are asked – to diagnose diseases and prescribe treatments. However, this reactive and linear approach, based on the diagnosis-treatment dichotomy, is no longer tenable in the era of the Green Deal. Instead, plant pathologists of the future will need to be designers and managers of complex agroecosystems. Their tasks will be to ensure sustainable plant health, to safeguard global food security without compromising future resources. In this strategic mission, the plant pathologist becomes an essential link between ecological regeneration and international economic stability.

"Plants are the sister of animals: like animals, they live, feed, and reproduce. To understand the former, it is often useful to consult the latter; just as, to understand the latter, it is appropriate to seek clarification from the former". These words, written more than a century ago by Jean-Henri Fabre (1823–1915), remain strikingly relevant, and serve to reinforce the view that plant health is an essential pillar of a balanced and comprehensive concept of One Health. Accordingly, any initiative aiming to advance One Health must integrate the interconnected

dimensions of plant, animal and human health within a unified framework.

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