Chapter

Plant Medicine and Infectious Disease

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Abstract

Our planet since development has experienced a greater perspective of growth. Constituting millions of species exhibiting different kinds of relationships producing both correlational and mutual growth, sums up to the widespread evolutional changes we see today. Mankind as a separate entity within the avalanche of species plays a greater share of the role and thus contributes greatly to the growth and existence of this planet. After having to battle with intraspecies 'fight and survive' relation within his colony conditioning him into psychological, social, and emotional, problems; he unquestionably relates with other species in an interspecies relationship. Though this interspecies relationship does not produce only negative outcomes and raises positive outcomes as well, a great deal of it is a threat to mankind's survival and growth. One interspecies relationship that mankind experiences mutual benefits is that with plants and with species such as those of some virus, bacterial, protozoans, etc., he experiences a parasitic relationship with a lot of negative outcomes. The chapter "Plant and Infectious Diseases," explore the relationship between man and plants that heals him and his relationship with other kinds of species that renders him into illness. It talks about how plants can help us remedy infectious diseases.

Keywords: plants and infectious diseases, plants metabolites, plant medicine, phytomedicine, viral infections, protozoa infections, fungi infections, bacterial infections

1. Introduction

Plants are nature's source of food. Aside from the enormous benefits we derived from plants including shelter and protection, plants are the center of what heals us. Medicinal plants have been with us since the time of our ancestors. Earlier men utilized plants preparations to remedy diseases. They employed archaic means together with instincts, beliefs, observation, taste, and experience to categorized plants as remedies and poisons [1]. Today, the role of medicinal plants as remedies has extended beyond the ways of ancient men. The role of medicinal plants as remedies now hinges extensively on the chemistry of the plant. Based on scientific research, plants are now screened and tested [2]. Phytochemist talks of two groups of compounds in plants. These are the primary plant metabolites and secondary plant metabolites. The primary plant metabolites perform basic life functions and the secondary plant metabolites classify compounds that are important in other aspects such as the

ability to destroy or prevent the growth of certain causative agents of diseases [3–5]. The goal of scientists in the field of medicinal plants is to find which plant compound has potency against which causative agents of diseases. Many compounds have proven efficacy in treating many diseases. Some of these compounds serve as stepping stones in the synthesis of synthetic and variants of semi-synthetic compounds. These plants' compounds are with potencies and by screening and testing scientifically their remedies are safe and potent. With recent issues arising from synthetic compounds on the human body both short term and long term, medicinal plants deserve the attention and the urgency of the public as well as scientist. There is no time in history the demands for medicinal plants protection and usage should concern everyone than today. The outbreak of Covid'19 in Wuhan, China, since 2019, has claimed many lives and still claiming lives at the time of this writing. This is not the first of its kind. Infectious diseases keep claiming lives yearly across the globe. With research providing promising evidence of medicinal plants' potencies against many agents of infectious diseases, the world has no reason not to protect plants. Infectious diseases are grouped by the classes of their causative agent which are viral agents, bacterial agents, fungal agents, protozoa agents, helminth, and prions (agents devoid of any nucleic acid) [6–9]. Some plants have proven efficacy against all these agents [10]. With all these broad future expectations of medicinal plants, there are hundreds of medicinal plants on their way to extinction as a result of destructive human activities. This is the era the world should come together to support plants.

2. Plants, man, and infectious diseases

Man and plants as well as infectious agents have existed dating to time immemorable. The relationship between man, plants, and agents causing infectious diseases has not changed to this day. Plants provide us with shelter, nourishment, etc. Infectious diseases caused us infections. When we are infected by any of the infectious agents which you will read on later, we feel sick and experience abnormality in functions and sometimes structure.

Infectious agents have their route of entry or attachment to our body where they cause physiological changes. Some of these changes exhibit clinically on our skin, hands and nails, oropharynx, head and neck, eyes, neurons, heart and lungs, abdomen, musculoskeletal, and genitalia and rectum. Infections present with signs and symptoms some of which are unique to certain infectious agents. Signs include generalized erythema, splinter hemorrhages, finger clubbing, Janeway lesions, vasculitis, dental caries, candidiasis, tonsillar enlargement, lymphadenopathy, red eyes, neck stiffness, delirium, tachycardia, pericardial rub, ascites, joint swelling, discharge from the genitals, etc. [11]. When a man is infected with infectious diseases, the same plants that shelter man, and provide him with nutrients, etc. can again help man to battle infectious diseases.

2.1 Plants and our life (plants as pillar of life)

Imagine you woke up one day to the realization that every plant has died. Now, create a mental picture of this incident. What will the world look like—a world without plants? There will be no food. There will be no shelter. There will be no clean air. There will be a bad water cycle. And soon there will be no animals as well as other

organisms. Plants support essentially every life. Together with animals, other organisms, and the abiotic aspect of the ecosystem almost every life is impacted.

Plants are all the organisms belonging to the kingdom Plantae. They are eukaryotes capable of using water, carbon dioxide, and the energy from the sun to produce chemical energy which is stored and, in the process, releases oxygen into the atmosphere which animals and other aerobic organisms depend on for survival. The chemical energy, an end product of photosynthesis, is taken up by animals in the form of food and released through cellular respiration to support life.

Let us step back and analyze well the importance of plants to life. Within the ecology, there exists a sequence of matter and energy transfer from organism to organism. Every organism requires matter and energy for carrying out life processes. These basic requirements have to be transferred from one organism to another hinging on some extent of conservation. This means of matter and energy transfer between organisms is termed the food chain. The food chain is nothing more than feeding relationships between species in a biotic community. These feeding relationships start at the base with a producer, then the primary consumer, the secondary consumer, tertiary consumer, and so on. This trend implies that the producer has to find a way to offer the 'first' matter and energy needed to start the transfer and that is what they do well. The producers make their food which is in turn taken up by the primary consumer. The primary consumers are also in turn taken up by the secondary consumer which in turn are also taken up by the tertiary consumers and so on. The primary producers, the most important aspect of the food chain, are most often plants (and other autotrophs organisms—algae, cyanobacteria, and chemoautotrophs). Every organism involves in the food chain and food webs (several interrelated food chains) to retrieved energy to carry out its vital process which would have been a fantasy without the producers like plants.

What more? Plants are one of the agents in the oxygen cycle. Plants manufacture the majority of the air we breathe through photosynthesis (the same process through which they give us food.). The human body has water (H_2O) being the majority component that is formed from hydrogen and oxygen (the oxygen we get from plants is part of this oxygen). Aside from plants giving as essential oxygen needed for life, they purified the atmosphere by removing chemicals dangerous to life. The carbon dioxide we breathe out is exchanged for fresh oxygen. At no time in history has there been a rise in the Industrial Revolution than our time. The high demand of the Industrial Revolution presents its mayhem to man and the environment as the result of burning fossil fuel releasing dangerous chemicals into the environment. Despite the frequent burning of fossil fuel and the destruction of vegetation both on land and sea, we still enjoy the relatively stable level of atmospheric oxygen. What can we attribute this to other than the plants that we are still sharing the environment with?

Moreover, plants serve as the habitat for thousands of organisms. In, on, and under plants are thousands of animals that all contribute one way or the other to the existence of the ecosystem. Walk through any forest and you will be amazed at the diversity of life that the forest harbors. Tree kangaroo, giant panda, monkeys, rabbits, foxes, raccoons, squirrels, chipmunks, badgers, moose, bear, bobcats, deer, antelope, lynx, jaguars, elephants are to mentioned but few of wildlife that would have been homeless without the forest. Within the human settlements, plants provide shades moderating temperature, protecting the lands and settlements from wind and water destructions. Again, ornamental plants are employed in almost all human settlements for beautification purposes. Even after cutting plants and destroying their lives they

still give us logs from which many products including paper, furniture, houses, and more goodies that make our lives comfortable are retrieved [12].

2.2 Plants as medicine

Aside from all the enormous benefits of plants to mankind, plants remain the center of what heals us. Readers may be surprised to know many conventional drugs are from plants (e.g. **Table 1**). Aspirin, a nonsteroidal anti-inflammatory drug (NSAID) used in inflammation and as an analgesic was from Willow; Digoxin, a cardiac stimulant used in congestive heart failure and cardiac arrhythmia were from Digitalis; quinine from Cinchona, morphine from Papaver, and artemisinin from Artemisia. Across the world especially in Third World countries plant medicine has been integrated into the Primary Health care delivery system. People in Asia, Africa, and Latin America depend to a greater proportion on phytomedicine in the treatment of illness partly caused by the great vast of plant species in their part of the world. No apology should be made for placing plants at the center of man's source of healing.

The use of plants for the treatments of diseases predates the records of human history. History has it that plants were the source of remedies of Pythagoras, Galen, and Hippocrates. The earliest human ancestors discovered the healing potency of plants through factors such as instinct, taste, observation, and experience. By relying on trial-and-error, medicinal plants were differentiated from poisonous plants. However, in many cases, the when and how these medicines were first used was lost in pre-history. Pieces of knowledge of medicinal plants, harmful plants, and their mode of usage were passed from generation to generation through oral transmission. Later, writing replaced the oral transmission mode of conveying knowledge from generation to generation (e.g., the Egyptians Ebers Papyrus). These written pieces of knowledge became the great wealth of knowledge upon which further development and discoveries were made.

Though the ancients men depended on trial and error with the first patients as an experiment in screening their plant medicinal preparations, plants are now screened depending on the modern scientific methods of investigation which comprises of a team of botanists (a scientist specialized in the study of plants), phytochemists (a scientist specialized in the branch of organic chemistry dealing with the chemistry of plants), pharmacologists (a scientist trained in the sciences of drugs) and clinicians (a practitioner of medicine whose work focus more on clinical work other than laboratory experiments).

The potency of plants as medicines depends on their phytochemical constituents. Phytochemist focuses on these compounds which have been divided into Primary Metabolites and Secondary Metabolites. Primary metabolites which include amino acids, lipids, carbohydrates, proteins, and vitamins play physiological roles such as growth, development respiration, storage, and reproduction. Secondary metabolites are organic compounds produced by plants through metabolic pathways derived from the primary metabolite's pathway. These metabolites (secondary metabolites) are not directly involved in the basic life processes of the organism but they are essential in other activities. The identification of secondary metabolites opened the gateway for the use of plants as medicine. These compounds are shown to have biological activities. The secondary plant metabolites are grouped into Alkaloids, Saponins, *Lipids, Phenolics, Terpenes, and *Carbohydrates.

Alkaloids are nitrogenous compounds (at least a nitrogen atom that usually forms part of a heterocyclic ring structure with marked physiological actions in

Popular medicinal plants as a source of modern medicine or bioactive compounds		
Bioactive compounds	**Medical uses**	**Origin**
Acetyldigoxin	Cardiotonic	*Digitalis lanata*
Aescin	Antiinflamatory	*Adonis vernalis*
Ajmalicine	Treatment for circulatory disorders	*Rauvolfia sepentina*
Allantoin	Wound treatment	*Matricaria recutita, Symphytum Officinale,* etc.
Anabesine	Muscle relaxant	*Anabasis sphylla*
Anisodamine	Anticholinergic	*Anisodus tanguticus*
Anisodine	Anticholinergic	*Anisodus tanguticus*
Atropine	Anticholinergic	*Atropine belladonna*
Bergenin	Antitussive	*Ardisia japonica*
Betulinic acid	Anticancerous	*Betula alba*
Caffeine	Central Nervous System stimulant	*Camellia sinensis*
Camphor	Rubecient	*Cinnamomum camphora*
Cocaine	Anaesthetic	*Erythroxylum coca*
Codeine	Antitussive	*Papaver somniferum*
Colchicine	Anticancer	*Colchicum autumnale*
Curcumin	Choleretic	*Curcuma longa*
Deserpidine	Tranquilizer	*Rauvolfia canescens*
L-Dopa	Anti-parkinsonism	Mucana species
Digitalin	Cardiotonic	*Digitalis purpurea*
Digitoxin	Cardiotonic	*Digitalis purpurea*
Digoxin	Cardiotonic	*Digitalis purpurea*
Gossypol	Male contraceptive	Gossypium species
Hyoscyamine	Anticholinergic	*Hyoscyamus niger*
Menthol	Rubefacient	*Mentha species*
Methyl salicylate	Rubefacient	*Gaultheria procumbens*
Morphine	Analgesic	*Papaver somniferum*
Nicotine	Insecticide	*Nicotiana tabacum*
Noscapine	Antitussive	*Papaver somniferum*
Picrotoxin	Analeptic	*Anamirta cocculus*
Podophyllotoxin	Anticancer	*Podophyllum peltatum*
Quinine	Antimalarial	*Cinchona ledgeriana*
Reserpine	Antihypertensive	*Rauvofia serpentina*
Salicin	Analgesic	*Salix alba*
Scopolamine	Sedative	*Datura metel*
Tetrahydrocannabinol (THC)	Antiemetic	*Cannabis sativa*
Theobromine	Vasodilator	*Theobroma cacao*
Thymol	Antifungal	*Thymus vulgaris*

Popular medicinal plants as a source of modern medicine or bioactive compounds		
Bioactive compounds	**Medical uses**	**Origin**
Vinblastine	Anticancer	*Catharanthus roseus*
Yohimbine	Aphrodisiac	*Pausinystalia yohimbe*

Table 1.
Medicinal plants as a source of modern medicine [13].

man and animals). Alkaloids are widely distributed in the Kingdom Plantae especially in angiosperms (higher plants). Alkaloids are rarely found in lower plants. Commonly known plant families in Angiosperm with alkaloids include Papaveraceae, Apocynaceae, Rubiaceae, Berberidaceae, Solanaceae, Convolvulaceae, Ranunculaceae, etc. Example of alkaloids includes Caffeine (central nervous system agent with effects on respiratory and cardiovascular systems.), Vinblastine (an antineoplastic drug from *Catharanthus Roseus*), Nicotine (ganglionic cholinergic receptor agonist), etc.

Saponins are secondary metabolites that contain a high percentage of glycosides (saponin) which can produce stable frothing aqueous solution. Saponins are harmful by their ability to cause hemolysis when injected into the blood but are harmless when taken by mouth. Saponins are proven to possess pharmacological activities including analgesic, antineoplastic, etc.

Lipids are a heterogeneous group of compounds with long-chain fatty acids and glycerol and higher monohydric alcohols. Lipids include fixed oils, fats, waxes, lecithins, phosphatides, etc.; which are relatively insoluble in water but dissolve in organic solvents. Lipids are primary plants metabolites but have been known to possess pharmacological activities.

Phenols probably constitute the largest group of plant secondary metabolites. The phytochemistry of phenols reveals the possession of at least one or more groups of phenol. Phenolic classes of pharmaceutical interest include simple phenolic compounds, tannins, anthraquinones, and their glycosides, coumarins and their glycosides, naphthoquinones, flavone, and related flavonoid glycosides, anthocyanidins and anthocyanins, and lignans and lignin. Phenols have pharmacological properties including antioxidants, anti-inflammatory, etc.

Terpenes are secondary plants metabolites derived from 5-carbon isoprene units. The number of the isoprene units is the basis for terpenes classification. Prefixes such as Hemi, Mono, Sesqui, etc., are used before terpenes to represent the number of isoprene units which in this case are 1, 2, and 3 isoprene units respectively. Hemiterpenes represent a terpene with 1 isoprene unit and so on.

Carbohydrates just like lipids are primary metabolites but form part of a majority of secondary metabolites through glycoxidation linkage. Carbohydrates such as mucilage are used as demulcents employed in ulcer management and inflammatory digestive disorders [14].

2.3 Plants medicine and infectious diseases

At the dawn of civilization, dating back to hundreds of years, snake venom was drunk intending to confer immunity to snake bites. At a similar time, it was found that smearing cowpox on torn skin induces the body to fight against smallpox. Forwarding to 1796, Edward Jenner who is popularly known as the founder of vaccinology in the West was successful in his attempt in the discovery of a solution that will

later impact civilization till this day by inoculating a 13-year-old-boy with vaccinia virus (cowpox) and demonstrated immunity to smallpox leading to the discovery of the smallpox vaccine three years later. After this concept underwent medical and technological changes the years ahead, the concept of vaccine and vaccination has been employed across almost every corner of the world and enormous benefits reaped as well.

Despite medical and technological advancement in vaccinology leading to the availability and use of effective vaccines and antibiotics, the concept of infectious diseases still presents a great canker to humanity. To this day that vaccine can be produced in the shortest possible time made possible by the advancement of scientific knowledge leading to research costing millions of dollars, infectious diseases remain an essential problem to the world. Covid'19 outbreak since 2019 has claimed millions of lives across the world daring the elderly and the weak with low immunity as a result of old age, chronic diseases, immunosuppressive drugs, malnutrition, etc., to survive its blow. According to Robbins and Cotran's book, "Pathologic Basis of Disease," Eight Edition, more than 10 million people die each year of infectious diseases [15].

Infectious disease is an impairment of health or a condition of abnormal functioning caused by microorganisms mainly through a specific kind of contact. They can be caught through contact with infected people, infected environments, infected animals, or insect bites. An example includes acquired immunodeficiency syndrome (AIDS), Viral hepatitis, Syphilis, Lyme Disease, Common Cold, Giardiasis, Malaria, Influenza, Measles, Pneumonia, Salmonella infections, Tuberculosis, Whooping cough (pertussis), Rubella, Shingles, Onchocerciasis, Candidiasis, Aspergillosis, Clostridial Infections, etc. Agents responsible for infectious diseases include viruses, bacterial, prions, fungi, helminths, protozoa, etc.

The incessant evidence of the antimicrobial resistance and side effects of synthetic drugs which have been the mainstay of remedying infectious diseases should straighten the line that was once burnt and bring the attention of the global population to the importance of medicinal plants and traditional therapeutic system in remedying infectious diseases.

An attempt to use natural products (plant medicines) to remedy infectious diseases swings on two pivots. The first is to consider factors related to the patients. These factors which must be considered relating to the patients include the patient's previous health histories, susceptibility to infections, chronic diseases, ability to tolerate drug by mouth, age, sex (if female, whether with a child or pregnant). The second factor to consider is that relating to the type of infections and the causal organism.

What follows describes the infectious agents responsible for infectious diseases and further recommends plants medicines for their remedy or which has shown efficacy against such specific infectious agents.

2.3.1 Viruses

Viruses are submicroscopic obligate intracellular infectious agents, which by definition consist of genetic code, either DNA or RNA, enclosed by a protein coat that is sometimes encased in a lipid membrane. Viruses cannot replicate on their own. They, therefore, depend on the host cell's complex metabolic and biosynthetic machinery for their replication. Viruses as infectious agents can infect animals, plants, and microorganisms such as bacteria and archaea. Viruses exist outside their host as virions (also used to describe a fully assembled infectious virus), an inert independent viral particle; nucleic acid, and capsid (and a lipid envelop in some cases). Viruses such as

polio and tobacco mosaic virus can even be crystallized. With an infection, the main function of the virion is to deliver the genetic component (DNA or RNA genome) into the host cell so that the genome can be transcribed and translated by the host cell. Viruses are known to be the most numerous types of biological entities. There are millions of species of virus existing with only a few given a detailed description.

Viruses are grouped based on their nucleic acid genome (DNA or RNA and not both), the shape of their capsid (helical or icosahedral), the presence or absence of a lipid envelop, their mode of replication, the preferred cell type for replication (atropism), or the type of pathology.

Viruses are responsible for a great share of human infections including AIDS, Corona Virus Infection, Chicken Pox, Common Cold, Dengue fever, Lassa fever, Herpes zoster, Herpes simplex, measles, SARS, Rabies, Smallpox, Viral meningitis, Viral pneumonia, Viral gastroenteritis, Yellow fever, Cytomegalovirus infection, Ebola hemorrhagic fever, etc. Some viruses are responsible for transient illnesses such as colds and influenza while others are hard to be eradicated from the body. Many viruses have a propensity to cause latent infections by expressing their genome into viral protein. The majority of these viruses belong to the *Herpesviridae* family: Epstein-Barr virus, Varicella-Zoster Virus, etc. Hepatitis B virus is known in several cases to persist in the host cell for a longer duration of time causing latent illnesses which can be reactivated later. The human papillomavirus induced benign warts and cervical carcinoma. The same clinical manifestation can be depicted by different species of virus and the same virus can depict different clinical manifestations depending on factors such as host immune status and age. Viruses can spread through touch, saliva, and through the air, sexual contact, insects (known as vectors), and through sharing of contaminated items [16].

2.3.2 Plant medicines for viral infectious

Viral infection presents a lot of challenges in the health industry. When a living cell is invaded by viruses, they hijack the cell's internal machinery to produce more of their kind in the process destroying a lot of host cells. Viral infections remain an area of medicine for which specific treatments are lacking. In immunocompetent individuals, some viral infections resolve spontaneously on their own. For most viral infections such as those associated with the common cold, treatment involves symptoms relief and not targeting the viral agents per se. Antiviral agents are agents that target the viral agent preventing their replication in the host cell. These agents include plants. *Alchornea cordifolia* is used in Ghana as an antiviral agent [17]. Clausena *anisata* contains carbazole alkaloids that inhibit Epstein-Barr virus early antigen in Ragi cells [18]. *Bridelia ferruginea* contains the flavonoids quercetin, quercitrin, and rutin that have demonstrated antiviral effects against coxsackie, Herpes simplex, measles, parainfluenza, and polioviruses [19]. *Scoporia dulcis* contain scopadulcic acid C which potentiates antiviral effect [20]. Extract of *Momordica charantia* has demonstrated antiviral activity against *Herpes simplex* virus type 1 and the proteins alpha and beta-momorcharin have been reported to inhibit HIV *in vitro*. Other antiviral agents include *Argemone Mexicana* (leave and stem), *Aloe vera, Allium sativum, Acacia nilotica, etc.*

2.3.3 Bacteria

Bacteria are free-living organisms that are found almost everywhere on Earth. Bacteria are prokaryotes, meaning they have a cell wall mostly bound by peptidoglycan, a polymer of glycan and peptides, but lack a distinct nucleus and other organelles

due to the absence of internal membranes which distinguish them from eukaryotes. Bacteria are classified based on shape, Gram staining, and need for oxygen. There are three basic shapes. The spherical bacteria are spherical and known as the cocci, the rod-shaped bacteria are known as bacilli (others curved known as the vibrio) and the spiral-shaped bacteria are known as the spirilla. Under gram staining, bacteria can be either classified as gram-positive or gram-negative based on the bacterial cell wall's ability to retain the crystal violet dye during solvent treatment. The gram-positive bacteria retain the dye because of their single thick cell wall and appear purple-brown under the microscope and the gram-negative bacteria do not take up the dye because they have a thin cell wall squash in between two phospholipid bilayer membranes and appear red under the microscope. Bacteria that require oxygen for survival are aerobic bacteria and those that can survive where there is no oxygen are the anaerobic bacteria. Unlike viruses, some bacteria can survive and replicate outside their host. Not all bacteria are harmful. Some bacteria are used in industrial and medicinal processes. Bacteria help in the fixation of nitrogen into the soil from the atmosphere and are vital to the planet's ecosystem. The human body serves as a home for many species of bacteria in a symbiotic relationship. However, several species of bacteria have broken this symbiotic relationship and are pathogenically responsible for many infectious diseases including anthrax, cholera, bacterial meningitis, brucellosis, diphtheria, gonorrhea, Lyme disease, leptospirosis, Pneumococcal pneumonia, syphilis, tetanus, trachoma, tuberculosis, typhoid fever, Q fever, Pertussis, shigellosis, Rocky Mountain Spotted Fever, salmonellosis, tularemia, nocardiosis, campylobacteriosis, etc. [21–23].

2.3.4 Plant medicines for bacterial infections

History has it that antibiotics were limited to substances produced by microorganisms. In 1877 Louis Pasteur discovered that injecting Bacillus anthracis in animals protected them from developing anthrax. Years after Pasteur's discovery, Fleming observed that a colony of Penicillium notatum contaminant on Petri dish inhibited bacteria which lead to the discovery of penicillin. The trend continues leading to the discovery of other compounds. Long before this array of discoveries, nature has already instituted compounds in plants with antibacterial properties waiting to be discovered. Plants' source of antibiotics includes lichen, a thallophytic plant of the division Lichenes that occur as crusty patches or bushy growths on tree trunks, walls, roots, or bare grounds. Lichenes contain usnic acid or vulpinic acid that is known to possessed bacteriostatic properties. Plants belonging to the Order Coniferae have also demonstrated antibacterial activities; essential oils in Juniperus and Pinus spp. possess antibacterial activity. A sulfur-containing amino acid in garlic (alliin) has antibacterial activities. Aloe vera gel and ginger have antibacterial properties. Sesquiterpene ketones in dicotyledons such as hops (humulene and lupulene) and myrrh (furanodiene-6-one and methoxyfuranoguaia-9-ene-8-one; protoanemonine, in *Anemone pulsatilla* and many Ranunculaceae; sulfur-containing compounds in the Cruciferae; plumbagin in Drosera have all demonstrated antibacterial activities [24].

2.3.5 Fungi

Fungi are all the known species of organism belonging to the kingdom Fungi. Fungi include yeast, molds, smuts, mushrooms, and toadstools. Fungi are distinct from green plants. Fungi are eukaryotic organisms and possess thick chitin in their cell walls which separates them from other eukaryotic organisms and

ergosterol-containing cell membranes. Fungi can be found almost everywhere on earth. They are with both harmful and beneficial effects. Their characteristics are intermediate between algae and protozoa. They share with plants some characteristics which include possession of cell walls, liquid-filled intracellular vacuoles, microscopically visible streaming of cytoplasm, and they lack motility. Just like bacteria, fungi aid the return of scarce materials to the soil by decomposing animals and plants. Fungi exhibit mycorrhizae association with plants (a symbiotic relationship between the mycelium of a fungus and the roots of a vascular plant) in which they provide plants with some nutrients and water for growth and taking nutrients as well from the plant. Medicines such as penicillin (an antibiotic) were produced from the fungus *Penicillium notatum*. Fungi are also used in the agricultural industry for controlling insect pests on crops. Most species of fungi live in the soil where they can obtain their nutrients, and on living organisms including plants and animals. Fungi again are saprophytic organisms and feed on dead organic matter. Fungi just like animals are heterotrophic organisms (they lack chlorophyll) and depend on the absorption of dissolved organic molecules typically by secreting digestive enzymes into their setting. Despite the enormously beneficial effects of fungi, some fungi are responsible for a wide range of infectious diseases infecting both animals and plants. Fungi are responsible for infectious diseases classified into superficial, cutaneous, subcutaneous, systemic, and opportunistic infections. Superficial diseases involve the skin, hair, and nails. Some fungi invade the subcutaneous while others invade deep tissues destroying internal organs in the immunocompromised host. Opportunistic fungi are generally harmless in their normal environment but become harmful in an immunocompromised host. Infectious diseases caused by fungi include tinea, candidiasis, coccidioidomycosis, aspergillosis, blastomycosis, histoplasmosis, etc. [25].

2.3.6 Plant medicines for fungal infections.

Diterpenes in Taxodiaceae genera under the Coniferae order are known, antifungal agents. Leaves and pericarp of *J. regia* extract pharmacologically demonstrated to be antifungal. *Pterocarpus erinaceus* aqueous and methanolic bark extracts showed *in vitro* antifungal properties [26]. A 10-year human study has shown that the extract of *Senna alata* is an effective antifungal agent for the treatment of *Pityriasis versicolor* [27]. *Vernonia amygdalina* contains sesquiterpene lactones, vernolide, and vernodalol which have demonstrated antifungal activities [28]. *Acacia nilotica* extracts of the root bark and fruits are reported to have antifungal properties particularly against yeasts and *Candida albicans* [29]. Many plants demonstrated antifungal properties and the list is still counting.

2.3.7 Parasitic worms

Unlike the infectious agents discuss so far, parasitic worms also known as helminths are macro-parasites meaning they can be seen with the naked eye. They are highly differentiated multicellular organisms with complex life cycles. In some hosts (definitive hosts) they exhibit sexual reproduction and exhibit asexual reproduction in other hosts (intermediary host or vector). Helminths include the three groups of parasitic worms; nematodes or roundworms, trematodes or flukes, and cestodes or tapeworms. Nematodes are unsegmented worms with elongated rounded bodies pointed at both ends; mostly free-living but some are parasitic. Trematodes have external suckers usually for attaching to a host. Cestodes are ribbon-like flatworms.

While in the infected host, parasitic worms receive nourishment and protection while depriving their host of nutrients. Helminths are transmitted through water, food, soil, and vectors. An infected host can harbor the adult worm, immature stages, or their larval forms. Adult worms in their host produce eggs that can pass out through the stools of their host. Parasitic worms' infection severity depends on the number of parasites harboring in the host. Diseases can also be due to the inflammatory reaction to their eggs and larvae. Helminths are responsible for symptoms such as diarrhea, loss of appetite, fatigue, stomachache, anemia, skin rashes, fever, swellings, weakness, and weight loss [30].

2.3.8 Plant medicines for parasitic worm infections

The leaf extracts of *Adansonia digitata* exhibited anthelminthic activities [31]. *Sorghum bicolor* is considered anthelminthic in India. *Ocimum gratissimum* extracts have shown promising anthelminthic properties by their ability to inhibit glutathione S-transferases from parasitic nematodes [32]. *Momordica charantia* extract also has anthelminthic activity [33]. *Balanites aegyptiaca* also showed anthelminthic properties [34]. Plants are continuously screened and the list keeps on counting.

2.3.9 Protozoa

Protozoa are a group of one-celled eukaryotes minutes organisms either free-living or dependent on the host for support. Protozoa are non-photosynthetic and like animals depend on other matter for nutrients. Protozoa are more related to animals sharing common characteristics which include motility, lack of cell wall, etc. Their locomotive structures include the cilia (hairlike projections from the surface of their cell), flagella (a lash-like appendage that extends from the cell surface.). Some protozoa such as the amoeba moved by forming pseudopodia, a temporal outgrowth that is filled with cytoplasm flowing from the body of the cell. The parasitic protozoa form part of the major causes of infectious diseases ranging from asymptomatic to life-threatening, depending on factors such as the nature of the pathogen and the immune status of the host organism. Parasitic protozoa can be classified based on whether they are responsible for systemic or local infections. Systemic protozoal infections include malaria, sleeping sickness, babesiosis, Chagas' disease, toxoplasmosis, and leishmaniasis. Protozoa such as *Entamoeba histolytica, Giardia lamblia* are responsible for intestinal parasitic infections. Intestinal protozoa infectious are transmitted usually by the fecal-oral route through direct contact with the infected agents by ingesting contaminated food or water [35, 36].

2.3.10 Plant medicines for protozoa infections

The efficacy of plants as a remedy for protozoal infections is remarkable. In the clinical world, plants have been the source of the clinically used antimalarial drugs; quinine from *Cinchona spp.* and artemisinin from *Artemisia annua* with the former being the blueprint for the generation of varieties of synthetic antimalarial agents. Plants agents that have been found to kill or inhibit protozoa infections happen to plants containing phytochemicals such as alkaloids and terpenes. There is a lot of scientific evidence backing the use of alkaloids and terpenes in the treatment of protozoal infections but that does not necessarily mean all plants with alkaloids or terpenes can be used for such purposes. This is because some of those agents might

have the efficacy to kill or inhibit the agents but might be harmful in man and should not be considered. Plants with efficacy against protozoa infections include *Cryptolepis sanguinolenta, Holarrhena pubescens, Alstonia boonei (Apocynaceae), Artemisia annua. Cryptolepis sanguinolenta* contained the alkaloid cryptolepine used in the treatment of malaria [37]. The plant has also shown potency in the treatment of amoebiasis [38]. *Holarrhena pubescens* contain conessine which has shown potency in the treatment of amoebic dysentery. *Alstonia* contains alkaloids such as villastonine which have shown an *in vitro* antiplasmodial activity. *Artemisia annua* contained sesquiterpene lactone artemisinin which has shown activity against malarial. Other plants used in protozoal infections include *Cinchona pubescens, Aloe vera, Phyllanthus niruri, Rauwolfia vomitoria, etc.*

3. Threats to plant's life

It would not be doing enough still if our daily mission was to survive a plant life. Though that statement would not be more than fantasy when compared to what we see today, it would have survived mankind himself and his environment and created a livelihood in all his sector but would not still match all the benefits that he reaps from plants. I should say there are more bodies and resources towards the conservation of animal life than there are to survive plants life. Animals are important. They give us pet, food, leather, etc., and forms part of our society and they deserve the efforts to survive and protect them, but, are not plants that give us the ability to live to see our pets, eat meats, and use leather deserves much more attention? We do not need years of research (though they are available) to tell us hundreds of plants species are on the verge of extinction across the globe. Just a few years back, native African plants such as the *khaya senegalensis* were not easy to spot and now, it takes the journey of kilometers into a deep forest zone to spot one or two such plants. And this is happening across all the corners of the globe. If greater urgency and resources are not directed to curb the trend, it will happen earlier than expected—many species of plants will be finally extinct.

In this era where there is a rise in scientific interest in research assaying plants' phytochemicals and their potencies, it would not be long for plants to help us remedy diseases that synthetic products have failed to cure. This is happening and is not a fantasy. HIV-inhibitors named inophyllums have been isolated from *Calophyllum inophyllum*. *Ferula sumbol* has been found to contain coumarins that have shown anti-HIV activity [39]. But if these plants are extinct before they get to the laboratory, what is the hope of the world?

To talk of man involvements as threats to plants' lives, we can consider two separate concepts. One is his physical activities and two, his inactions. His activities include timber exploitations, agriculture, mining, industrialization, urbanization, etc. His inactions are his lack of concern towards the threats to plants' lives.

Man's conscious and unconscious activities threatened the lives of plants and many plants species are battling extinction as a result of such activities. Our desire for timber products instead of other variants is killing plants other than whetting our appetites. Mining, agriculture, and other activities are all gearing towards that path. All these activities result in habitat loss. The homes of these plants are converted into agricultural lands and places for livestock grazing. Industrial production and urbanization are rendering the natural habitats incapable of supporting plants life. Plants that were previously doing well in these habitats are killed in so doing reducing biodiversity.

Man's inaction that endangers plants lives on the other hand is the things he needed to do to immunized his physical activities that throw real danger on the plant's life that he is not doing. We are sending plants to extinction by choosing to do nothing. The logging of trees would not be so destructive as far as we replaced them. We could plant trees to replace those we cut. We could employ reafforestation to immunize deforestation. On an individual level, we could decide to plant trees in our environment as a means of providing shades, beautifying our environment, and in the process, preserving plant life. You could inform someone today of the importance of protecting plants' lives and helping spread the good news. Each and everyone can choose to do nothing or choose to do something. Whatever we choose to do, the process would not be easy. Choosing to protect plants' lives is hard. Doing nothing and watching nature fades away is hard. I am asking you today to choose your hard!

3.1 Recommendations

The journey to protecting plants' lives is everyone's job since everyone is affected positively by the presence of plants. Environmental protection agencies, governmental and non-governmental agencies, individuals, and the whole populace should awake and rethink all the practices that endanger plants species. New bodies aimed at preserving vegetations should be created and already existing ones should be strengthened. Governments, as well as individual philanthropists, should donate towards these bodies making sure they are well equipped to function. Sectors such as the farming sectors that are found of practices that endanger plants' lives should be monitored and those found guilty sanctioned. Frequent campaigned towards plants plantation should be encouraged as well as mass education on the benefits of protecting the vegetations.

Human resources are the center of all the types of resources in the sense that nothing will be meaningful and minimum rewards can be reaped from every resource without trained human resources to channel their course. Aside from preventing plants from extinction, experts should be trained to work and research on plants. Scientists already in the field should be well motivated and channels should be created for others to enter the field.

With the availability of plants and scientists to work on them, plants medicine will propel medicine to a horizon we never anticipated.

4. Conclusions

The above concepts are not claiming all there is to medicinal plants and infectious diseases but it is enough to straighten the logs that were bent years ago. Medicinal plants worked magic for the ancient men and survived them and their generation. If care, enough urgency, and resources are directed towards the preservation of plants, medicinal plants will change the perspective of medicine and impacts generations to come. If we stay adamant and watched as many species of plants suffer extinctions, the world will lose this greater facet of nature and there will be no room to contain the mayhem. Diseases are with us. The world might record new outbreaks of infectious diseases, but with strategic plans that do not exclude interventions geared towards the wellbeing of medicinal plants, any kind of infectious disease can be easily controlled.

Notes/thanks/other declarations

I acknowledge the strength given me by God and my greatest thanks go to Him. And to my brother Cantey Zorngo and sister, Sefa Agartha for the love we share. To Esther Anokyewaa Akoto, you mean the world to me, thank you.

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