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Review

Plant Nutrition for Human Health: A Pictorial Review on Plant Bioactive Compounds for Sustainable Agriculture

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Abstract: Is there any relationship between plant nutrition and human health? The overall response to this question is very positive, and a strong relationship between the nutrition of plants and humans has been reported in the literature. The nutritional status of edible plants consumed by humans can have a negative or positive impact on human health. This review was designed to assess the importance of plant bioactive compounds for human health under the umbrella of sustainable agriculture. With respect to the first research question, it was found that plant bioactives (e.g., alkaloids, carotenoids, flavonoids, phenolics, and terpenoids) have a crucial role in human health due to their therapeutic benefits, and their potentiality depends on several factors, including botanical, environmental, and clinical attributes. Plant bioactives could be produced using plant tissue culture tools (as a kind of agro-biotechnological method), especially in cases of underexploited or endangered plants. Bioactive production of plants depends on many factors, especially climate change (heat stress, drought, UV radiation, ozone, and elevated CO_2), environmental pollution, and problematic soils (degraded, saline/alkaline, waterlogged, etc.). Under the previously mentioned stresses, in reviewing the literature, a positive or negative association was found depending on the kinds of stress or bioactives and their attributes. The observed correlation between plant bioactives and stress (or growth factors) might explain the importance of these bioactives for human health. Their accumulation in stressed plants can increase their tolerance to stress and their therapeutic roles. The results of this study are in keeping with previous observational studies, which confirmed that the human nutrition might start from edible plants and their bioactive contents, which are consumed by humans. This review is the first report that analyzes this previously observed relationship using pictorial presentation.

Keywords: climate change; salinity; drought; biofortified crop; nutrients; degraded soil; plant secondary metabolites; elevated CO_2

1. Introduction

The agroecosystem includes soil, cultivated plants, and other compartments [1]. This system has basic ecological and nutritional functions for human health, including fluxes of nutrients and energy and their interactions among different species, which control global food production [1]. The world's population is expected to exceed 10 billion by 2050, and the world's food production needs to increase more and more [2]. This food production is primarily dependent on crop productivity, and it is primarily controlled by the molecular–physiological functions of plant mineral nutrients and their deficiency [3]. Plant-derived nutrients are crucial for human nutrition and maintenance of human health [4]. There is no human nutrition without crop production, which itself must be supported by proper and sufficient plant nutrients [5]. These plant nutrients can play a crucial role in sustainably promoting agricultural production on cultivated lands, facilitating soil carbon sequestration, and taking pressure off global peatlands and forests [6]. Recently, several studies have reported on plant nutrition and its impact on human health, with topics such as the role of plants in human health with a focus on greening biotechnology [7], responsible plant nutrition [8], and the relationship between plant nutrition and food security under climate change [9]. It is also worth mentioning recent studies on the potential of aromatic, rare, and endemic wild species found in extensively controlled agroecosystems that have never used by humans [10,11], including crop wild relatives [12].

There is increased concern about the concept of medicinal plants for human health and their importance for general well-being, rather than solely for consumption as human foods [7]. These plant foods represent the main source for most mineral macro- and micronutrients, which are essential elements for human nutrition, as well as a range of bioactive ingredients, which can support preventing many chronic diseases such as Alzheimer's, cataracts, cancer, cardiovascular disease, diabetes, and age-related functional decline [4,7]. Therefore, vegetable and fruit plants are important parts of the human diet, which can contain proteins, carbohydrates, amino acids, fatty acids, lipids, and vitamins (i.e., A, B complex, C, E, and K). Edible plants could be applied in the field of phytomedicine because of their nutritional value, which mainly is due to the high contents of the previously mentioned compounds, in addition to many bioactive ingredients for overcoming several human diseases [13–17]. Several current reports have been published that investigate the role of agro-techniques (different agricultural technologies) in producing plant bioactives by using plant tissue culture tools [18,19] or agro-wastes such as banana peels [20], olive mill pomace [21], and coffee leaves [22].

Therefore, this photographic review is an attempt to highlight the field of plant nutrition and its importance for human health. This review will focus on edible plants as vital components of the human diet, which contain essential mineral nutrients, several bioactive compounds, and vitamins to prevent several human diseases. Plant nutrition management for human health will also be discussed, including many case studies, such as plant nutrition management under salt-affected and contaminated soils.

2. Methodology of the Review

Photographic reviews are generally rare in various published sources, because it is difficult to find suitable photos in each section of the MS of a suggested or edited review. A photographic review can provide a "complete story" on a particular topic. Therefore, the main idea of this review emerged from the importance of plant nutrients and their role in many human diseases. This photographic review focuses on plant nutrition, which includes some important sections on human health, based on the common association of "good plant nutrition for good human health". After searching the main websites of major publishers, several published materials (i.e., reviews, mini-reviews, original articles, chapters, etc.) were collected and sorted to build the sections of this review. Therefore, the table of contents (TOC) was very flexible at the first stage of writing the review and by the time some changes were needed. The main sections in the TOC depended mainly on the field of plant nutrition and its relationship to human health from different points of view such as "plant nutrition and sustainable agriculture", "plant nutrients uptake and their physiological functions", "the medicinal plants and bioactive compounds", "plant nutrition management for human health", "plant nutrition under climate change", "plant nutrition under pollution", and "plant nutrition and stressful soil". After organizing the TOC, the main ideas started to be written down through collecting the required materials from main sources, published mainly during the last 5 years (2018–2022), such as ScienceDirect, SpringerLink, PubMed, MDPI, and Frontiers. Because this review is a photographic study, many photographs and drawing figures (in cases of absence or unavailability of relevant photos) were inserted in this study, because these figures are informative and summarized.

3. Plant Nutrition and Sustainable Agriculture

Plant nutrition deals with nutrient uptake, intravascular motility, nutrients' roles in plant growth and development, and the physiological and biochemical functions of nutrients in plants. The field of plant nutrition in general is illustrated in Figure 1. This science also includes the main methods for applying fertilizers or nutrients, the relationship between plant nutrition and human health as expressed in phytomedicine, and management of different cases of plant nutrients, particularly under environmental stresses in in vivo (Figure 2A,B) or in vitro studies (Figure 3). There are many methods that can be used to carry out studies on plant nutrition, including in vivo (in the field, greenhouses, pots, etc.) and in vitro (in the lab) methods, and they may use soilless culture, hydroponics, or micro-farm systems. These methods have different classifications, such as controlled and noncontrolled experiments [23,24], in vitro and in vivo studies, and quotative and qualitative studies [25].

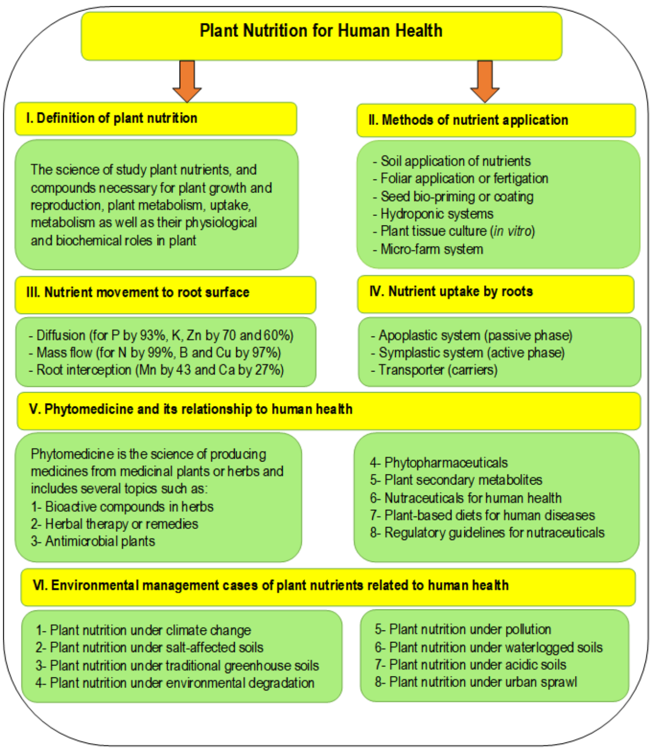


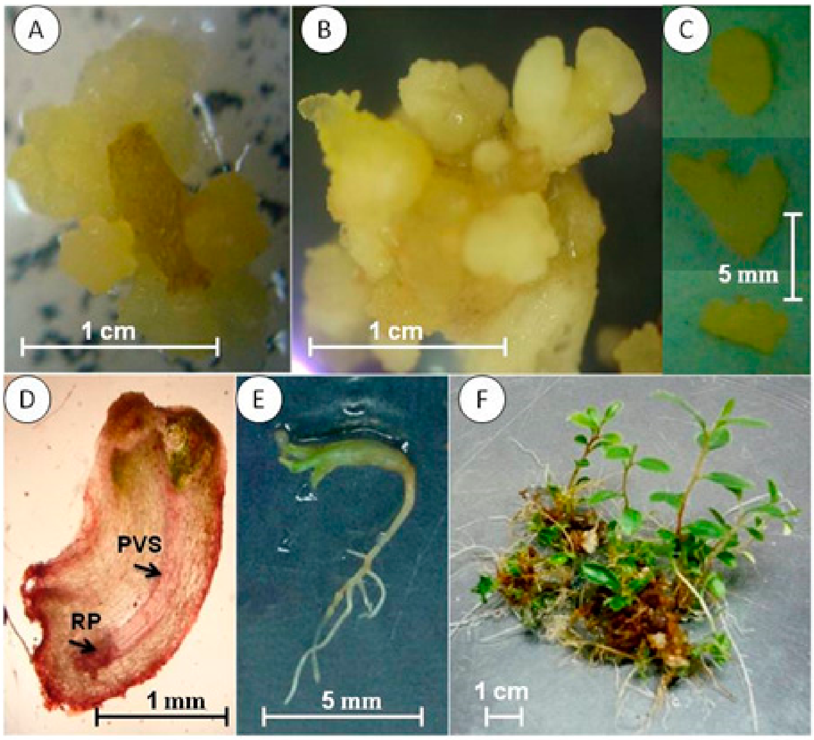
Figure 1. An overview on the field of plant nutrition, which includes the definition, methods of possible study, uptake by roots, phytomedicine, different management cases, and links to human health. Sources: [23–26].

(**A**) (**B**)

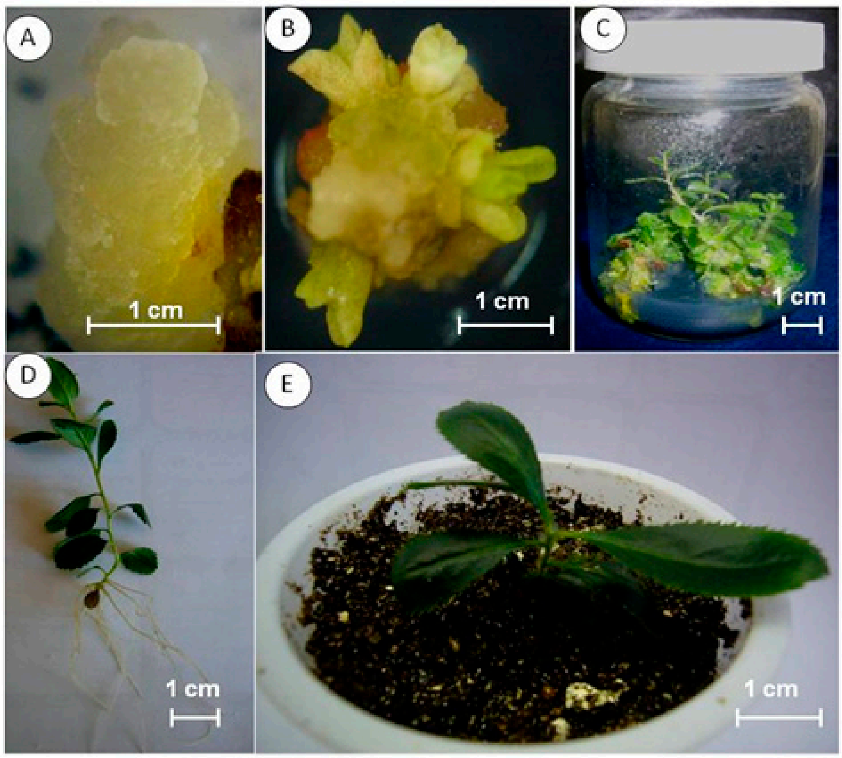
Figure 2. (**A**) Some photos of in vivo studies for plant nutrition investigations. The upper photos are from open field and greenhouse (the upper photos of cucumber and lettuce) and different hydroponic systems (the 4 middle photos of lettuce and tomato), whereas the lower photos (citrus plants) represent the soil application of mineral (super phosphate) and organic fertilizers (organic manure). These agricultural systems are found in the experimental farm at Kafrelsheikh University. (**B**) More studies on plant nutrition could be investigated within open field (the upper photo left), forest (the upper photo right), and greenhouse using different growing systems (the middle photos), whereas the lower photos represent the micro-farm system using growing media or without growing media. All photos by El-Ramady.

The world's population is constantly increasing. Therefore, food security in the 21st century is a serious concern [5]. A total of 17 Sustainable Development Goals (SDGs) were adopted as part of a new 15-year sustainable development strategy. Ending hunger, achieving food security and improving nutrition, and promoting sustainable agriculture are among the 17 aims. The four most relevant time-sensitive goals are as follows:

1. By 2030, ending hunger;
2. By 2030, ending all malnutrition forms;
3. By 2030, doubling agricultural productivity;
4. By 2030, ensuring sustainable food production systems [27].



Group no. (1)



Group no. (2)

Figure 3. A case study for plants in vitro as a promising tool for plant nutrition. **Group (1)**: Somatic embryogenesis of strawberry tree (*Arbutus unedo* L.), where photos (**A**,**B**) are of embryogenic callus; (**C**) different stages of embryo (globular, heart, and torpedo); (**D**) torpedo stage of embryo; (**E**) cotyledonary stage of embryo; (**F**) plantlets initiated from somatic embryos. **Group (2)**: Indirect propagation of strawberry tree, where photo (**A**) is of callus induction; (**B**) callus differentiation; (**C**) shoot formed from callus; (**D**) shoot rooted; (**E**) acclimatized plants. All photos by El-Mahrouk.

Agriculture confronts several obstacles worldwide, making it extremely difficult to meet its primary goal of supplying food and nutrition security to an increasing population [28,29]. Figure 4A,B presents some essential obstacles that face agriculture and farming livelihoods. These obstacles affect the energy for agro-practices, animal farming, intercropping, irrigation and drainage water and their efficacy, wastes from agriculture and domestic life, and seedlings and their preparing. Poor soil fertility, low levels of available mineral nutrients in the soil, improper nutrient management, and a lack of vegetation genotypes with higher tolerance to nutrient deficiency or toxicity are currently main limitations associated with food insecurity, malnourishment (i.e., micronutrient deficiencies), and ecological degradation in many developing countries [5]. Research in plant nutrition removes these restrictions and, as a result, provides important knowledge that is extremely beneficial in ensuring sustainable food security and well-being for humans without harming the environment [5]. To achieve the desired crop yield, chemical fertilizers are overused [30]; however, chemical fertilizers have been used for centuries and have greatly enhanced agricultural yields [31]. The overuse of chemical fertilizers has resulted in soil, environmental, and aquatic pollution, particularly soil mineral imbalances, degraded soil structure and soil fertility, soil quality deterioration, eutrophication, and ground water and air pollution, all of which are severe long-term barriers. Furthermore, the uncontrolled use of chemical fertilizers boosts production costs while decreasing farmer profit. To keep intensive agriculture productive while decreasing negative environmental consequences, systematic measures to restore natural resources are essential [30,31]. It has also been observed that traditional agricultural techniques are related to excessive usage of agrochemicals. As a result, the agricultural sector requires modification in order to achieve self-sufficiency in food production and provide healthy and safe food in the face of climate change difficulties. One such solution that solves agricultural problems may be the practice of sustainable agriculture [29].

Bioenergy or biorefinery crops are mainly the plants that are compatible with sustainable agriculture such as Jerusalem artichoke (*Helianthus tuberosus* L.), alfalfa (*Medicago sativa* L.), fruits, vegetables, grains, and other food and fiber crops [32]. These several plants and their biodiversity can promote sustainable agriculture [33]. Especially in the context of plant nutrition and agricultural sustainability, to address the dilemma of chemical fertilizer overuse, it is necessary to create smart materials that can deliver nutrients to specific places while still contributing to a clean environment. According to recent research, graphene is a promising material that might be used as a transporter for plant nutrients. It is capable of delayed and regulated nutrient release for the benefit of the plants, resulting in increased agricultural yield with minimal environmental effect [31]. Because nanoparticles have unique physicochemical properties, such as high surface area, high reactivity, their pore size distribution, and their particle shape, nanotechnology opens up a wide range of novel applications in the fields of plant nutrition required to meet the future demands of the growing population. The management of optimal nutrients for sustainable crop production is a priority topic in agricultural research. In this respect, nanonutrition has proven to be the most intriguing field of research, focusing on the provision of nano-sized nutrients for sustainable crop development [34]. These nanofertilizers and/or nano-amendments could apply to different common problematic soil cases such as saline/alkaline, waterlogged, or compacted heavy-clay-content soils, which should be managed through cultivation of the right selected crop that can be tolerant against such previously mentioned obstacles, particularly under arid and semi-arid conditions (Figure 5).

(**A**)

Figure 4. *Cont*.

(**B**)

Figure 4. (**A**) Some creative technologies that boost agricultural output while protecting environmental quality, which may include saving the required energy for different agricultural practices (the upper photos), saving proper and sufficient feeds of farm animals (the 3rd and 4th photos), intercropping using horticultural crops (the 5th and 6th photos), domestic wastes and their sorting/collecting in certain containers (the 7th and 8th photos of horticultural plants), and irrigation canals and drainers and their efficiency (the 9th and 10th photos). All previous agro-practices need to be sustained. All photos by El-Ramady. (**B**) The production of seedlings in agricultural nurseries is very important, using different materials for growing media to supply the agriculture in field or greenhouse with healthy seedlings. All previous agro-practices need to be sustained. All photos of horticultural seedlings (such as pepper and tomato) by El-Ramady.

Thus, agriculture may achieve sustainability by using creative technologies that boost agricultural output while protecting environmental quality. Damage to agricultural soil constitute a serious problem in developing countries, which lead to a decrease in arable lands due to urbanization and human activities, especially industrialization (Figure 6). At this point, the usage of nanohybrid constructs such as nanofertilizers (NFs) has gained prominence [30]. Nanofertilizers are nano-enabled bulk materials that are applied to increase plant nutrition. Furthermore, they have been described as next-generation fertilizers that may enable us to ensure global food security, continue improving the nutritional value of food through Fe and Zn agronomic fortification (ZnO, Fe_3O_4), maintain balanced nutrition to alleviate biotic and abiotic stresses, and decrease ecological footprint, resulting in lower agrochemical use and nutrient losses [35]. Nanofertilizers can also improve nutrient availability and uptake efficiency (by more than 20%) compared to conventional fertilizers, increasing plant production and nutritional value in specific crops [35]. The nanoparticles may not be stimulated quickly to be taken up by plants, but a series of processes such as oxidation and recombination may occur to give the plants the necessary micronutrients. Because the nutrients are of nanoscale size, fortifying the plant with such nanonutrients appears to be an appealing choice. Plants not only develop but also accumulate such nutrients, bridging the nutritional deficit gap. Furthermore, nanofertilizers might be designed to target specific nutritional deficiencies in plants. This is feasible because the atoms on the surfaces of nanomaterials may be arranged to have distinctively diverse characteristics [31]. In addition, NFs boost plant nutritional efficiency while, simultaneously, reducing the toxicity of chemical fertilizers. As a result, they assist developing nations, particularly in building sustainable agricultural initiatives [36]. NFs also have the following advantages: nutrient-delivered control can be interlinked to soil nutrient balance, plant growth phase, and environmental factors using nanosensors [35]. One of the environmental factors that impacts the efficiency of NP application is the agricultural system (in open field, greenhouse, pots, in vitro, etc.). Thus, plant production under greenhouse conditions is very important in addressing one of the great challenges that face developing countries, particularly those under the stress of arid and semi-arid conditions. Greenhouses have many benefits in winter as protected houses for crop production; however, due to a lack of facilities in developing countries, a range of troubles may face this production method related to soil salinization, indoor temperature and aeration, control of the soil moisture content, etc. (Figure 7).

Figure 5. Cultivation in saline/alkaline, waterlogged, and compacted heavy-clay-content soil needs to manage the right crop that can be tolerant against certain obstacles, particularly under arid and semi-arid conditions. These problems include accumulation of salts on the soil surface, growing the salinity-loving grasses, waterlogged soil (the upper photos of grasses), salinity/alkalinity stress (the middle photos of maize), sodium appearance in dispersion of soil particles on the soil surface (lower photos of common purslane and lettuce), etc. All photos by El-Ramady.

Figure 6. Urban sprawl causes several forms of damage to agricultural soils such as building on these soils, discarding the wastes of building or construction, and collecting and storing several wastes on these soils. These photos of damage can impact agricultural production from arable lands and food security. All photos from different places in Egypt by El-Ramady.

Figure 7. Agricultural production under greenhouse conditions is very important for developed countries, especially during the period of falling snow in winter, as greenhouses are protected houses for crop production, and for developing countries, particularly under arid and semi-arid conditions, which may face a range of troubles with lack of facilities, aeration (the upper left photo), control of the soil moisture content (the middle and lower photos of cucumber and pepper), etc. All photos by El-Ramady.

In addition to using nanofertilizers for providing sufficient nutrients and avoiding many problems, many modern approaches have been adopted to achieve these targets in sustainable ways. Recently, scientists around the world have been looking at the potential function of nanoparticles in biotechnology because of their ability to transfer DNA and other substances to plant cells. In this regard, introducing C nanotubes into chloroplasts has resulted in a success for plants' enhanced capacity to capture more light energy. Furthermore, these tubes might be used as artificial antennae for catching light wavelengths that are outside of their regular range, such as ultraviolet, green, and near-infrared [34]. DNA-based biosensors (genosensors) have recently been extensively developed for toxins detection [37]. The use of material identification to integrate nanomaterials with biosensors increases electron flow between electrodes. Electrochemical nanobiosensors have several advantages, including low cost, high sensitivity, and low identification threshold. Such sensors are extensively used in labs due to their ease of use and measurement [38]. Sensors made using nanoscience and nanomaterials have a wide range of applications in the present day. For example, using enzyme-based NSs is one of the most useful analytical techniques for finding toxins in biological materials [39]. Such approaches (i.e., nanosensors and DNA nanosensors) play a vital role in monitoring toxicity and deficiency in plant nutrients, enhancing the ability to face such challenges as limitations to plant growth and development. In this context, Podar and Maathuis [40] reported that plants evolved sophisticated systems to enhance nutrient usage efficiency, because nutrients are scarce and important resources. Monitoring external and internal nutrient levels is critical for adjusting processes including absorption, redistribution, and cellular compartmentation. Primary sensors, which often include transceptors or transcription factors, are used to measure nutrient levels. Plants' primary receptors for some nutrients are just now being recognized. There is considerable knowledge about how members of the nitrate transporter 1 family sense the external nitrate state. Potential sensors for additional macronutrients such as potassium and salt have recently been found, while transcription-factor-type sensors for micronutrients such as zinc and iron have been described [40].

4. Plant Nutrients Uptake and Their Physiological Functions

Cultivated plants need nutrients for their growth and development, including essential (e.g., N, P, K, Ca, Mg, Mn, Fe, B, Zn) and beneficial nutrients (e.g., Se, Si, Na). When the cultivated plants can uptake all required nutrients, this will be reflected in the productivity, which will be higher. Plants contribute significantly to the global food chain by providing elements such as carbohydrates, proteins, edible oils, dietary fibers, vitamins, and minerals in forms such as vegetables, fruits and grains [41,42]. They also supply us with medication, clothing, construction materials, biofuels, pulp, and other products. As a result, improved plant growth and health would directly benefit nations' economies and development [43]. Plant nutrition is concerned with the relationship between soil nutrients and plant development [44]. Plants require at least 14 mineral elements in addition to O_2, CO_2, and H_2O for optimal nutrition. Plant development and agricultural production are reduced when any of these minerals are deficient. Six mineral elements are required in large quantities, these being N, P, K, Ca, Mg, and S, whereas Cl, B, Fe, Mn, Cu, Zn, Ni, and Mo are required in small quantities [45]. The uptake of nutrients for plant growth under different environmental conditions may be influenced by the soil conditions, especially degraded soils such as salt-affected soils. The main problem that faces cultivated plants under salt-affected-soil conditions is salinity and/or alkalinity stress, which may lead to deficiency of some nutrients and/or some physiological disorder in the leaves of these cultivated plants (Figure 8A,B).

(**A**)

(**B**)

Figure 8. (**A**) Plant growth under different environmental conditions may cause a problem in uptake of some nutrients from soils, especially degraded soils such as salt-affected soils. The main problem that faces cultivated plants under salt-affected-soil conditions is salinity and/or alkalinity stress,

which may lead to deficiency of some nutrients. These photos represent some nutrient deficiency and/or some physiological disorder in the leaves of some cultivated horticultural crops. All photos of guava, apricots, pears, and peaches were taken from the experimental farm at Kafrelsheikh University by El-Ramady. (**B**) More photos of the obstacles facing cultivated plants under degraded conditions in particular salt-affected soils. The main problem that faces cultivated plants under salt-affected-soil conditions is salinity and/or alkalinity stress, which may lead to deficiency of some nutrients. These photos represent some nutrient deficiency and/or some physiological disorder in the leaves of some cultivated horticultural crops. All photos of citrus, pears, and guava plants were taken from the experimental farm at Kafrelsheikh University by El-Ramady.

Mineral nutrients play an essential function in plant metabolism. A lack of any mineral nutrient inhibits plant growth, which has a direct relationship with the plant's production potential (Table 1). Mineral nutrients are involved in the creation of vital organic molecules such as amino acids and proteins, and nutritional imbalance can affect a variety of biological processes [46]. Nutrient deficiency and toxicity adversely affect crop health, resulting in the emergence of strange visual symptoms and decreased crop yields [44]. To increase yields in locations with limited phytoavailability, important mineral elements are applied to the soil as fertilizers. Furthermore, fertilizers with critical minerals for human nutrition are periodically applied to crops in order to boost their concentrations in edible parts for the benefit of human health [45].

Table 1. A list of nutrient biological functions in plants and suggested deficiency symptoms.

Nutrient Element	Nutrient Symbol	Uptake Form	Nutrient Biological Functions in Plants [Ref.]	Deficiency Symptoms of Nutrients [Ref.]
Nitrogen	N	NH_4^+ and NO_3^-	Constituent of amides, amino acids, proteins, nucleic acids, nucleotides, coenzymes, chlorophyll, etc. [47]	Inhibits plant growth; yellowing or chlorosis of leaves due to a collapse in chloroplasts [48]
Phosphorus	P	$H_2PO_4^-$; HPO_4^{2-}	Constituent of nucleic acids and lipid membranes, ATP, etc. [49]	Dark greenish-purple leaves, with necrotic spots and malformed [49]
Potassium	K	K^+	Controls more than 60 enzymes, mainly of photosynthesis and respiration [50]	Chlorosis of older leaves; shorter internodes in stems; inhibiting protein synthesis [49]
Calcium	Ca	Ca^{2+}	Ca-pectate is main constituent of cell wall; controls elongation and division of cells; activates many enzymes [47]	Small and younger leaves; deformed and chlorotic, bitter pit (apple); black heart (celery) [50]
Magnesium	Mg	Mg^{2+}	Component of chlorophyll and polyribosomes; enzyme cofactor [51]	Chlorosis of intervein and streaked or patchy effects on leaves [50]
Sulfur	S	SO_4^{2-}	Component of amino acids (i.e., cysteine, cystine, and methionine), CoA and vitamins (biotin; thiamine), and glucosides in onions [44]	Interveinal chlorosis. S-deficiency chlorosis in all leaves at the same time; yellowish-green [49]
Boron	B	$H_2BO_3^-$	Involved in many processes: proteins synthesis, respiration, sugars transport metabolism of RNA, plant hormones, and carbohydrate [52]	Mainly appears on younger leaves; malformed and bluish-green; retaining flowers, forming of pollen [47]
Copper	Cu	Cu^{2+}	Essential respiration and photosynthesis of mitochondria; component of major enzymes Cu-Zn-SOD [52]	Necrosis, spots at tips of younger leaves, white tips, die back, and reclamation disease [49]
Chlorine	Cl	Cl^-	Essential for osmoregulation and photosynthesis; increases resistance to plant diseases (rice; barely; corn) [53]	Leaf chlorosis, curling of leaves, plant wilting, and restricted branching in root system [52]

Table 1. *Cont.*

Nutrient Element	Nutrient Symbol	Uptake Form	Nutrient Biological Functions in Plants [Ref.]	Deficiency Symptoms of Nutrients [Ref.]
Iron	Fe	Fe^{2+}	Essential for respiration; assimilation of N, mitochondria, photosynthesis; hormones biosynthesis; cytochromes; Fe-containing proteins (haem) [52]	Interveinal chlorosis from younger leaves; leaf margins and veins remain green; stunted growth in palms leads to meristem death [54]
Nickel	Ni	Ni^{+2}	Essential for prokaryotic enzymes such as hydrogenases, dehydrogenases; component in urease enzyme [55]	Leaf-tip necrosis; nitrate in leaves accumulation; Ni deficiency in pecan called mouse-ear leaves [55]
Manganese	Mn	Mn^{2+}	Exists in several plant cell enzymes; involves many enzymes (i.e., lyases, hydrolases); proteins Mn-SOD [56]	Interveinal chlorosis in dicots; smallest leaf veins remain green; speckled yellow in sugar beet [47]
Molybdenum	Mo	MoO_4^-	Essential for N-assimilation, phytohormone biosynthesis S-metabolism; controls N-assimilation enzymes [52]	In young plants: dwarfed plants, mottling, grey tinting, cupping and flaccid leaves [44]
Zinc	Zn	Zn^{2+}	Component of synthesis protein enzymes; essential catalytic for more than 300 enzymes, Zn-Cu-SOD [47]	Interveinal chlorosis; internodes short, younger shoots; smaller leaves; malformed, rosetted [50]

Plants absorb necessary components from the soil via their roots and from the air via their leaves (mostly N and O) [46,57]. Cation exchange, in which root hairs pump H^+ into the soil via proton pumps, is responsible for nutrient uptake in the soil. These H^+ displace cations linked to negatively charged soil particles, making them accessible for root absorption. Stomata open in the leaves to take in CO_2 and exhale O_2. In photosynthesis, CO_2 molecules serve as a C supply. The root, particularly the root hair, is a vital organ for nutrient intake. The root's morphology and architecture can influence nutrient absorption [46]. The nutrients required by plants are supplemented by fertilizers with the belief that they are mainly absorbed by plants. Micronutrient deficiency is shown by irregular development of plant tissues; nevertheless, this may not mean the soil is insufficient for micronutrients; rather, the root may be unable to absorb and translocate the nutrients due to limited root pore size. To fulfill the demands for food of the rising population, it is consequently critical to investigate techniques for boosting crop quality and key nutrients [31].

Plant growth and development are strongly influenced by the combination and concentration of available mineral nutrients in the soil. Because of their relative immobility, plants frequently encounter considerable challenges in receiving an appropriate supply of essential nutrients to fulfill the demands of basic cellular functions. A lack of any of the required elements may result in reduced plant production and/or fertility. Nutrient deficiencies can induce stunted growth, plant tissue death, or leaves yellowing due to a decrease in the production of chlorophyll, a pigment required for photosynthesis. A lack of nutrients can have a substantial influence on agriculture, resulting in lower crop yield or plant quality. The nutrient deficit can also limit overall biodiversity, because plants are the producers that support the majority of food webs [58]. By 2100, the world population is expected to reach 11.0 billion. As a result, existing food production must be increased by 60–70% to fulfill the calorie demands of the rising population. Global future food demand can only be met by improving resource usage efficiency without reducing agricultural yields by advancing current science and technology. Chemical fertilizers have increased agricultural productivity in developing countries by 50–55%. However, the usage efficiency of supplied nutrients via fertilizers remains relatively low (N: 30–40%, P: 15–20%, K: 50–55%, and micronutrients: 2–5%). This results in excessive soil nutrients mining, resulting in a net negative soil nutrient balance of about 10 million tons and hence deteriorating soil health [30].

5. Medicinal Plants and Their Bioactive Compounds

Medicinal plants are defined as plants that have a wide variety of bioactive compounds exhibiting several biological activities and beneficial properties, including antioxidant, antiviral, antimicrobial, anticancer, anti-inflammatory, anti-aging, antihypertensive, and neuroprotective attributes [59]. Medicinal plants are of great potential all over the world, due to their healthy consumption and/or their application as extract supplementation for traditional medication (Figure 9). A remarkable number of studies can be found on the therapeutic attributes of medicinal plants combined with a growing concern for their use as natural products (e.g. [60–63]). Medicinal plants represent 25–50% of the current production of drugs that are used in the sector of healthcare from various sources [62]. It is expected that the medicinal plant field will continue supporting new medicine derived from natural products during the coming decades [61]. The mode of action of these medicinal plants mainly depends on the extracted/used parts, including flowers, leaves, fruits, roots, seeds, and stems, which are considered rich sources of bioactive compounds [64].

It is well known that medicinal plants can be consumed as fresh foods or applied as extracts to foods or pharmaceutical products. For selecting medicinal plants, there are different strategies that can be used, as reported by [26] in Figure 10. Concerning plant functional traits and their potential for human health, there are several general themes such as antimicrobial plants [65,66], plant secondary metabolites [67], nutraceuticals for human health [68], plant leaf protein concentrates [69], biofortified plants for human health [70], plant-based diets for human diseases [17,71], and herbal bioactive-based products for different applications such as cosmetics [72,73]. Plant-based diets have important benefits for human health, which prevent or decrease many human diseases such as cardiovascular, dermatological, endocrinological, gastrointestinal, ophthalmological, genitourinary, otolaryngological, musculoskeletal, neurological, and respiratory diseases [65].

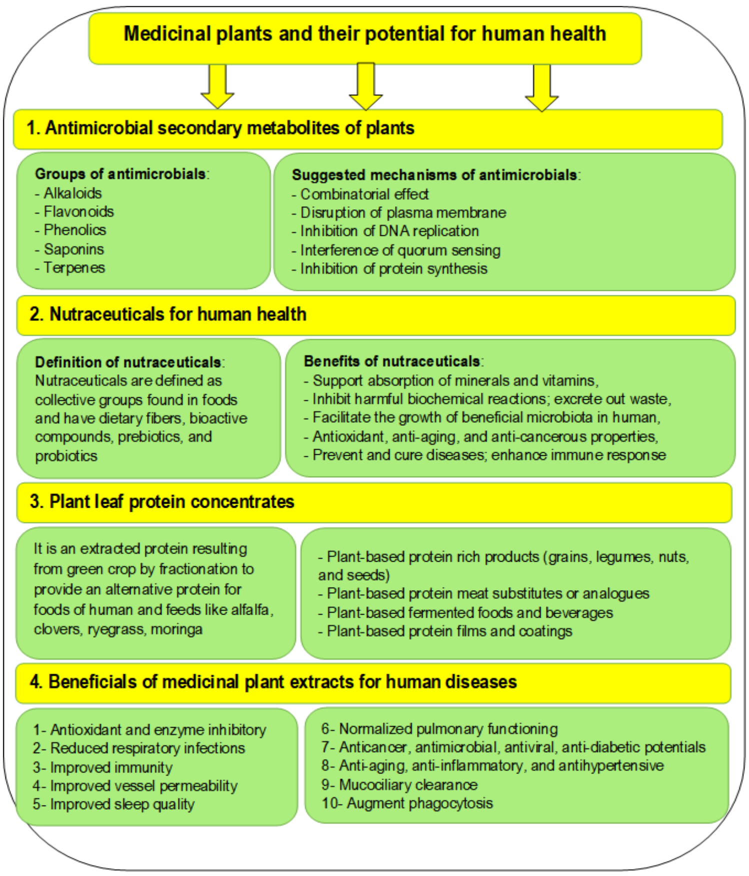


Figure 9. Medicinal plants may be used in plant-based diets, which are very important. These diets can guarantee support for the human body. The functions of medicinal plants may include

antimicrobial secondary metabolites and their potentials, nutraceuticals for human health, plant leaf protein contrate, and plant-based diets. GHGs, greenhouse gasses emissions. Sources: for group (1) [67], (2) [68,74], (3) [75–77], (4) [78–80].

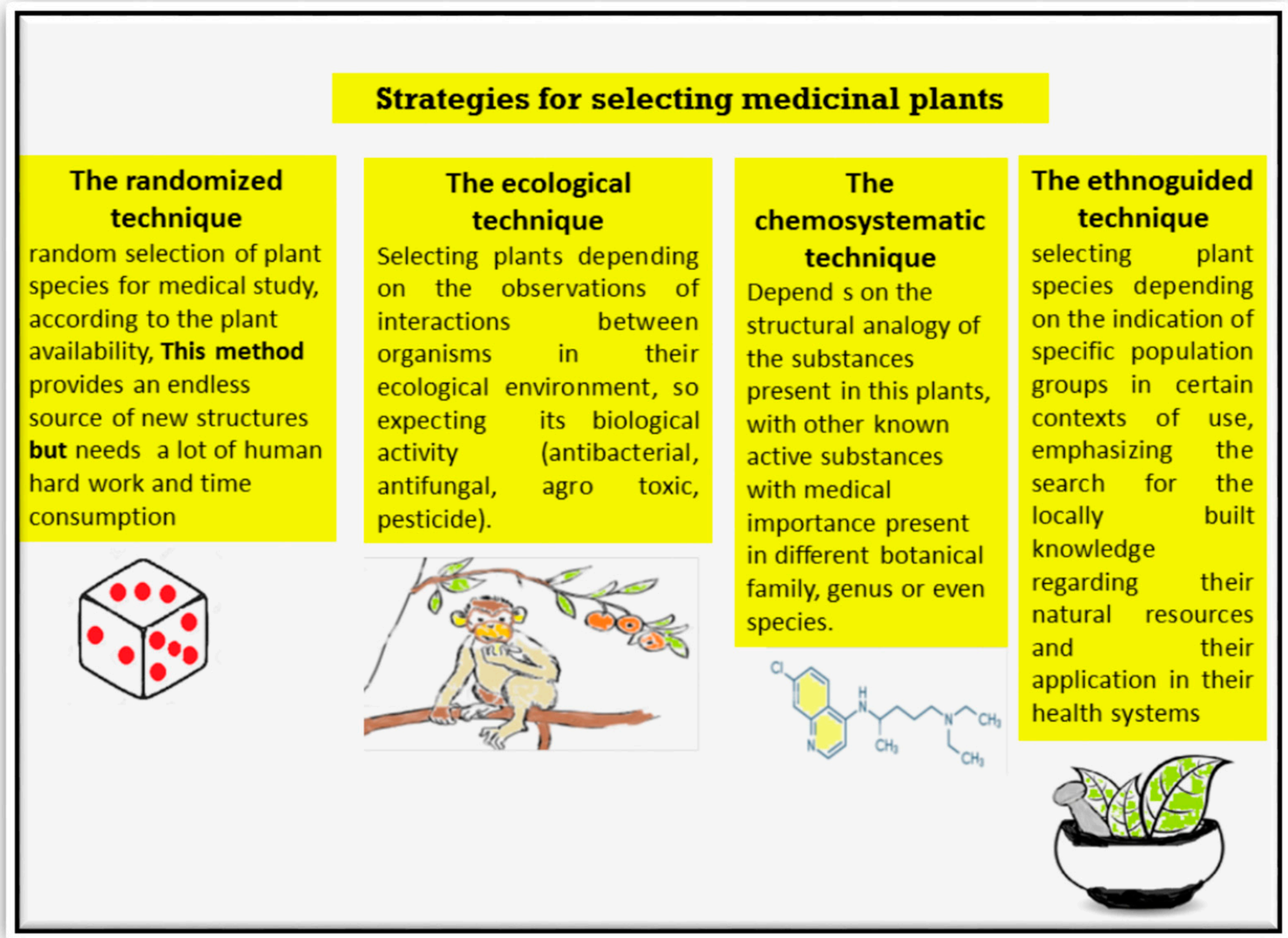


Figure 10. Different strategies that could be used for selecting medicinal plants according to [26,81].

All plant species can form primary metabolites in cells, but secondary metabolites vary by plant species and can be produced through metabolic pathways derived from the primary metabolic pathways. Both primary (e.g., chlorophyll, carbohydrates, fats, proteins, lipids, and nucleic acids) and secondary metabolites are active compounds in plants that have a variety of functions. Plant secondary metabolites could be defined as organic compounds that are produced by plants but are not directly involved in plant biological processes, including growth, development, and reproduction [82]. These metabolites have numerous functions in plants, including plant growth and development processes, innate immunity, defense response signaling, and response to environmental stresses [83] as well as root microbiomes [84] (Figure 11). Secondary metabolites can also be used as food additives, pharmaceuticals, and cosmetics ingredients [85]. Enormous plants, mainly medicinal plants, that can produce bioactive secondary metabolites include Chinese medicinal herbs, as reported by El-Ramady et al. [86] and in Tables 2 and 3. The production of bioactive plant secondary metabolites is common using in vitro technologies [87,88].

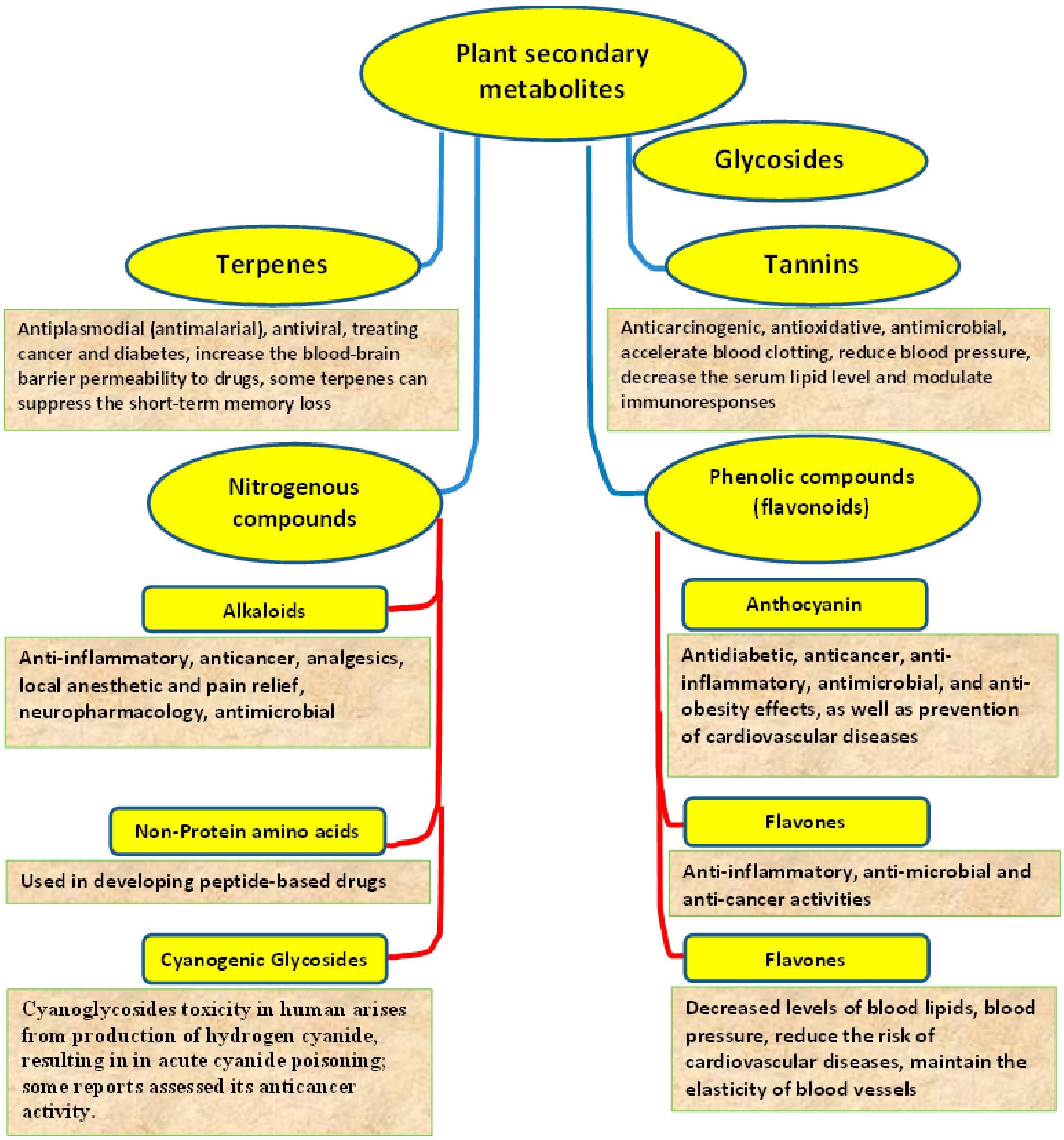


Figure 11. The major groups of plant secondary metabolites could in general be classified into many large molecular families such as alkaloids, flavonoids, phenolics, terpenes, and steroids as well as by their therapeutic effects on human health.

On the other hand, nutraceuticals have great potential for human health. They can help and support the absorption of vitamins and minerals, preventing their deficiency. They can also inhibit harmful biochemical reactions, detoxify cells, facilitate the growth of beneficial microbiota, and excrete out wastes [89]. Nutraceuticals have some medical properties such as anti-aging, antioxidant, and anti-cancerous attributes, which can enhance different biochemical processes and structures [89]. These attributes also may augment phagocytosis, induce immunomodulatory effects, enhance immune response, prevent hypersensitivity, and reduce auto-immune response [90]. Nutraceuticals can help prevent and cure many diseases related to cancer, diabetes, neurodegeneration, and hypertension [68].

The world suffers from chronic undernourishment, especially in Africa and Asia. Therefore, different natural sources for human nutrition are very important, including animal sources and traditional or underutilized plants. Consumption of plants is important, whether they are consumed as a fresh source for human nutrition or as extracts added to foods or to drugs due to their high contents of bioactive compounds. Therefore, several traditional, wild, or underutilized plants, including many vegetables and legumes, could be consumed by humans to improve human health (Table 2). These plants contain certain bioactive compounds or phytochemicals (e.g., alkaloids, lectins, glucosinolates, organic acids, polyphenols, terpenes, and volatiles), which have important roles in preventing several chronic human diseases such as diabetes, cancer, and diseases of the heart, through many biological activities such as anticancer, antioxidant, antihypertensive, antimicrobial, anti-inflammatory, and hepatoprotective attributes [91].

Table 2. List of some underexploited or underutilized plants, their used part, their common use, and their bioactive compounds as medicinal plants. All scientific names according to Plants of the World Online (https://powo.science.kew.org/, accessed on 25 June 2022).

Common Name(s)	Scientific Name	Plant Family	Commonly Used Plant Part(s)	Common Uses	Refs.
Adzuki bean	*Vigna angularis* (Willd.) Ohwi and H. Ohash	Fabaceae	Seeds	Seeds for cooking with rice	[92]
Andean lupin, pearl lupin	*Lupinus mutabilis* Sweet	Fabaceae	Seeds	Seeds for culinary use	[93]
African yam bean	*Sphenostylis stenocarpa* Hochst ex. A. Rich. Harms	Fabaceae	Seeds, tubers	Seeds for culinary use	[94]
Bambara nut or groundnut	*Vigna stenocarpa* L. Verdc	Fabaceae	Seeds	Seeds for foods and beverages	[95]
Deer-eye beans, donkey-eye bean	*Mucuna* spp.	Fabaceae	Seeds	Seeds for culinary use	[96]
Jack beans, sword bean	*Canavalia* spp.	Fabaceae	Pods and seeds	Pods as vegetable; seeds for culinary use	[97]
Ground bean, Hausa groundnut	*Macrotyloma geocarpum* (Harms.) Maréchal and Baudet	Fabaceae	Seeds like peanuts	Seeds for culinary use	[98]
Hyacinth bean, lablab bean	*Lablab purpureus* L.	Fabaceae	Leaves, seeds	Seeds used culinarily	[99]
Horse gram	*Macrotyloma uniflorum* (Lam.) Verdc.	Fabaceae	Seeds	Seeds for culinary use	[100]
Peavines, vetchlings	*Lathyrus* spp.	Fabaceae	Pods, seeds	Seeds for culinary use	[101]
Moth bean	*Vigna aconitifolia* (Jacq.) Marechal	Fabaceae	Pods, seeds	Seeds for culinary use	[102]
Stinky bean	*Parkia speciosa* Hassk.	Fabaceae	Pods, seeds	Pods and seeds for culinary use	[103]
Rattlepods	*Crotalaria* spp.	Fabaceae	Leaves, flowers, pods, seeds	Leafy vegetable; seeds for culinary use	[104]
Rice bean	*Vigna umbellata* (Thunb.) Ohwi and H. Ohashi	Fabaceae	Seeds	Seeds for culinary use	[105]
White lead tree, subabul	*Leucaena leucocephala* (Lam.) de Wit	Fabaceae	Pods	Young pods used as vegetable	[106]
Winged bean	*Psophocarpus tetragonolobus* (L.) D.C.	Fabaceae	Leaves, seeds, bean pods, roots	Entire winged been plant is edible	[91]
Amaranth	*Amaranthus* spp.	Amaranthaceae	Leaves, seeds	Leafy vegetable, oil, pigments	[107]
Black nightshade	*Solanum nigrum* L.	Solanaceae	Leaves, fruits (berries)	Leaves and berries as food prepared by cooking	[108]
Common purslane	*Portulaca oleracea* L.	Portulacaceae	Leaves, stem	Leafy vegetable	[109]
Curcuma	*Curcuma* spp.	Zingiberaceae	Rhizomes, roots, leaves	Roots edible, rhizomes culinary	[110]
Bitter melon, spiny gourd	*Momordica* spp.	Cucurbitaceae	Fruits	Fruits as vegetable	[91]
Indian poke	*Phytolacca acinose* Roxb.	Phytolaccaceae	Leaves	Leafy vegetable	[91]

Table 2. *Cont.*

Common Name(s)	Scientific Name	Plant Family	Commonly Used Plant Part(s)	Common Uses	Refs.
Mallow leaves	*Corchorus* spp.	Malvaceae	Leaves	Leafy vegetable	[91]
Parsnip	*Pastinaca sativa* L.	Apiaceae	Roots	Root vegetable like carrot	[91]
Prickly pear	*Opuntia* spp.	Cactaceae	Leaves or cladodes	Leaves cooked as a vegetable	[96]
Squash, pumpkin	*Cucurbita* spp.	Cucurbitaceae	Leaves, fruits, seeds	Fruits for culinary	[111]
Sea kale	*Crambe* spp.	Brassicaceae	Leaves	Leafy vegetable	[91]
Tassel hyacinth	*Leopoldia comosa* (L.) Parl.	Asparagaceae	Bulbs	Bulbs as vegetable	[112]
Tomatillo	*Physalis philadelphica* Lam.	Solanaceae	Fruits	Green fruits as vegetable	[91]
Yellow cresses	*Rorippa indica* (L.) Hiern	Brassicaceae	Tender shoots, leaves	Leafy vegetable	[91]
Water spinach	*Ipomoea aquatica* Forssk.	Convolvulaceae	Leaves	Leafy vegetable	[113]
Water leaf, Ceylon spinach	*Talinum triangulare* (Jacq.) Willd.	Talinaceae	Leaves	Leafy vegetable	[114]

On the other hand, several bioactives derived from plants have been used in therapeutic applications. Before these applications, certain strategies are required to identify these bioactive compounds in plant extracts through a guide for identification of bioactive compounds. These strategies depend on the plant extract, its bioactivity pattern, and the facility of isolation. In general, the main strategies that can be used in the identification of bioactive compounds from plant extracts may include bioactivity-guided fractionation, synergy-directed fractionation, a metabolic profiling approach, a metabolism-directed approach, and direct phytochemical isolation [81]. However, more research on this topic needs to be undertaken before the association between plant bioactives and therapeutic activities is more clearly understood. Recently, a great concern for plant bioactives and therapeutic agents has been reported in the literature (e.g. [81,85,115]), as reported in Table 3.

Table 3. List of some important medicinal plants and their bioactive compounds and their therapeutic applications or medicinal effects. All scientific names according to Plants of the World Online (https://powo.science.kew.org/, accessed on 25 June 2022).

Plant Species	Therapeutic Agent	Target Disease	Ref.
Artemisia annua L.	Artemisinin	Malignant treatment	[116]
Artemisia obtusiloba Ledeb.	Arglabin	Cancer chemotherapy	[81]
Amorpha fruticose L.	Monoterpene and sesquiterpene	Antibacterial, insecticidal, and cytotoxic effects	[85]
Calophyllum lanigerum Miq.	Calanolide A	Type-1 HIV	[85]
Capsicum annum L.	Capsaicin	Postherpetic neuralgia treatment	[81]
Cannabis sativa L.	Dronabinol; Cannabidol	Chronic neuropathic pain	[81]
Caragana sinica (Buc'hoz) Rehder	Collagen and aggrecan	Preventing degradation of cartilages	[117]
Carthamus tinctorius L.	Serotonin/N-feruloyl serotonin	Preventing degradation of cartilages	[118]
Cephalotaxus harringtonia (Knight ex J.Forbes) K.Koch	Homo-harringtonine	Oncology treatment	[81]
Colchicum spp.	Colchicine	Gout disease	[81]
Conium macularum L.	Coniine	Poisonous, neurotoxin	[119]
Cinchona succirubra Pav. ex Klotzsch	Quinine	Antimalarial	[120]
Dalbergia sissoo Roxb. ex DC.	Flavonoids (Tectorigenin)	Anti-degradation of cartilage proteins	[121]
Euphorbia peplus L.	Ingenol mebutate	Actinic keratosis treatment	[81]
Galanthus woronowii Losinsk.	Galantamine	Alzheimer's disease	[122]
Galega officinalis L.	Metformin	Anti-diabetic	[85]
Larrea tridentata (DC.) Coville	Masoprocol	Cancer chemotherapy	[81]
Nigella sativa L.	Thymoquinone	Osteoarthritis treatment	[115]
Oroxylum indicum (L.) Kurz	Oroxylin A	Anti-degrading markers of cartilages	[123]
Papaver somniferum L.	Morphine	Acute pulmonary disease and breath shortness	[124]
Papaver somniferum L.	Codeine	Analgesic and anti-diarrheal properties	[125]
Papaver bracteatum Lindl.	Thebaine (paramorphine)	Analgesic	[126]
Phyla nodiflora (L.) Greene	Nepetin	Osteoarthritis treatment	[127]
Rhus succedanea L.	Rhoifolin	Preventing degradation of cartilages	[128]
Pueraria lobata (Willd.) Ohwi	Puerarin	Against cartilage degradation	[129]

Table 3. *Cont.*

Plant Species	Therapeutic Agent	Target Disease	Ref.
Sarcotheca griffithii (Planch.) Hallier f.	Crude extract	Cough	[130]
Solanum spp.	Nicotine	Anti-inflammatory and stimulant	[131]
Solanum tuberosum L.	Solanine	Anticarcinogenic	[132]
Solanum lycopersicum L.	Tomatine	Anticancer and immune effects	[133]
Talinum triangulare (Jacq.) Willd.	Acrylamide and phaeophytin	Cuts, wound, scabies, and peptic ulcer	[134]
Taxus brevifolia Nutt.	Paclitaxel	Antimitotic agent for various cancers	[81]

6. Plant Nutrition Management for Human Health

Mineral malnutrition is unfortunately a common problem in both developing and industrialized countries, with estimates suggesting that up to two-thirds of the world's population may be at risk of deficiency in one or more critical mineral elements [135,136]. Nutrient deficiency is considered one of humanity's most severe concerns, from which millions of people suffer. According to Brevik et al. [137], at least 25 mineral elements are likely to be required for human health, and plants are the main providers of the majority of these nutrients. Iron (Fe), Zn, I, Se, Ca, Mg, and Cu are the most deficient mineral elements in the human diet [138]. For a variety of reasons, edible plants may not contain enough mineral elements for human nutrition. These reasons may include the genetics of plant species with low content of certain mineral elements, differences between crops in their mineral phytoavailability (such as for Cu, Fe, and Zn in alkaline or calcareous soils), and plant anatomy, including restricted phloem mobility of elements in edible portions such as seeds, fruits, and tubers at low concentrations [45]. Therefore, there is an urgent need to produce edible plants with sufficient and proper nutrients for human nutrition, which could be achieved using many strategies, especially biofortification approaches [139]. The application of nutrients to cultivated plants is called biofortification, which can be achieved by agronomic and genetic biofortification and nanobiofortification (Figure 12).

The biofortification process is effective in enriching many crops, mainly staples, with nutrients such as Fe, Cu, Mn, Ca, Zn in addition to folate and vitamins [140–143]. The enrichment of food with essential or required nutrients is called fortification. The main reason for biofortification is fighting hidden hunger, which results from consumed foods not having enough nutrients (essential vitamins and micronutrients such as Fe, Cu and Zn), especially in sub-Saharan Africa and South Asia [144]. Thus, a long history of food fortification all over the world is known, including margarine, butter, and sugar using vitamin A, salt (fluoride and iodine), and milk using vitamins [144]. The historical background of biofortification may include conceptualization (1950–1990), realization using research (1990–2000), and producing of biofortified crops (2001–2020) [144].

Plant nutrition management is one of the most important global challenges that faces human life, and it must be managed with a holistic approach through responsible plant nutrition [145]. The future of plant nutrition and its challenges can be highlighted using this approach as a new paradigm that depends mainly on the food system and circular economy to achieve multiple environmental, socioeconomic, and health objectives. This new paradigm for managing plant nutrients could be presented through the following questions, as suggested by Dobermann et al. [145]:

1. How can the world increase crop productivity to double its current amount, especially under the global nutrient imbalance?
2. How can the world guarantee this production to double or triple, particularly in developing countries such as African nations under unbalanced inputs of human nutrition?
3. What is the role of precision or smart farming in accelerating the adoption by farmers of more solutions for precise nutrient management?
4. What are the sustainable solutions for decreasing the losses of nutrients, such that their wastes along the whole agri-food chain are halved?
5. To what extent can the nutrient cycles in the farming of crops and livestock be made closed?

6. What are the key measures to improve and sustain soil health?
7. What is the main role of mineral nutrition of different crops and its changes in a changing climate?
8. To what extent can applied fertilizers reduce greenhouse gas emissions?
9. What is the main role of cropping systems in producing high crop quality and more nutritious foods?
10. To what extent can we monitor nutrients for implementation of 4R nutrient stewardship?

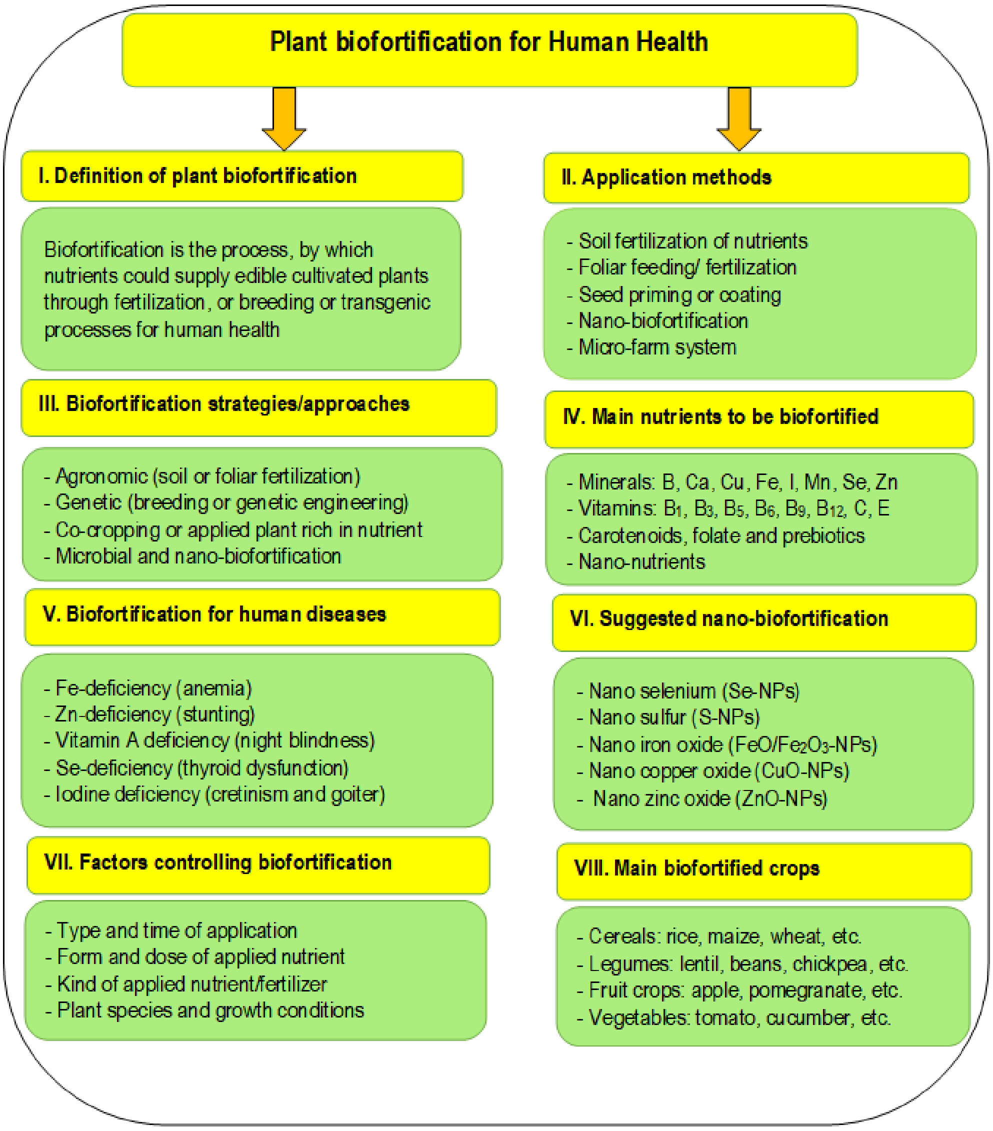


Figure 12. Biofortification process, including the definition, applied methods, different strategies, different nutrients that can be biofortified, factors controlling this process, and the main crops, which can be biofortified.

Therefore, the sound management of plant nutrition can be achieved when this management overcomes the main problems that face plant nutrition through the following objectives: (1) improving nutrient efficiency, crop productivity, and then farmer income, (2) increasing the recovery of nutrients and their recycling from wastes, (3) improving and sustaining soil health and its quality, (4) enhancing human health with tailored nutritious crops, and (5) minimizing greenhouse gas emissions, nutrient pollution, and biodiversity loss [145]. In the following sub-sections, it is shown that some challenges facing plant nutrition can be managed in some selected case studies, including climate change conditions, pollution, and problematic soil, with focus on plant bioactive compounds.

6.1. Plant Nutrition under Climate Change

Climate change affects all of human life, especially the agricultural sector, in addition to the fields of environment, ecosystems, socio-economics, and socio-politics [146]. Climate change has threatened the sufficient supply of food and its production due to irreversible weather fluctuations [147]. Due to several shifts in optimum temperature ranges of many plant species, climate change has influenced the survival of many species, thereby accelerating the loss rate in their biodiversity and changing the ecosystem structure [147]. Plants are undergoing considerable environmental change as a result of human activities, such as climate change caused by increases in atmospheric CO_2 and other greenhouse gasses, which is raising average and severe high temperatures and changing precipitation patterns (Table 4; [6,148]). Climate change, as a crucial component of global ecosystems, has had a profound impact on human, plant, and animal cycles and processes. For optimal growth and development, the plants need some mineral nutrients, which are significant components of a variety of macromolecules (i.e., nucleic acids, phospholipids, amino acids, and co-enzymes). These molecules play a role in plant cellular metabolism, and it is reflected positively in physiological properties of the plant (i.e., chlorophyll synthesis, redox reactions, plasma membrane integrity, and cell osmotic potential), as reported by Soares et al. [149]. Furthermore, these climatic changes are significantly related to water-use efficiency, drought sensitivity, and high geographic variability in soil nutrients, which provide a complex environment that influences soil microbial activity and nutrient availability. The impact of climate change on plant nutrition, including nutrients and their availability to cultivated plants, has reported by Elbasiouny et al. [6], and more details on climate change, its impacts, and mitigation are presented in Figure 13.

Table 4. The current changes in greenhouse gas emissions of main gasses during different periods.

Period Studied	CO_2 (µmol mol^{-1})	CH_4 (ppb Volume)	N_2O (ppb Volume)
1800	280.0	0.80	288
2017	405.0	1.72	325
2022	420.23	1.90	334

Sources: Cracknell and Varotsos [150], https://www.co2.earth/ (accessed on 21 May 2022).

To understand how plants respond and adapt to these climatic changes, several studies have looked into the problem from various angles, such as the effects of N and increased CO_2 or N and water stress on various elements of plant structure and function, as well as the impacts of CO_2 on the quality of plant as food and nutrient translocation within plants. Three homologous pairs of species common in semi-arid environments in California have been studied using serpentine soils (usually high in Mg and low in Ca and N) and non-serpentine soil [151]. The authors showed that non-serpentine species were more tolerant for a wider range of nutrients and water, owing to their rapid growth and greater capacity to adapt than serpentine species. Furthermore, they expected that high water availability and nutrients would benefit all species more than low water availability and nutrients. In addition, they measured plant growth responses in the context of functional traits (e.g., relative growth rate, root mass ratio, and photosynthetic nitrogen-use efficiency) in a greenhouse study, and one of their key findings was that functional traits based on nutrient use and allocation explained more response variability than other traits. Furthermore, they discovered that, contrary to expectations, species responded best to a mix of low water and high nutrients, regardless of their origin. Under elevated CO_2 concentrations from 400 to 800 ppm, the accumulation of nutrients, especially K and Mg, was significantly increased, whereas phosphorus was decreased in leaves, stems, and roots of *Asparagus racemosus* [152].

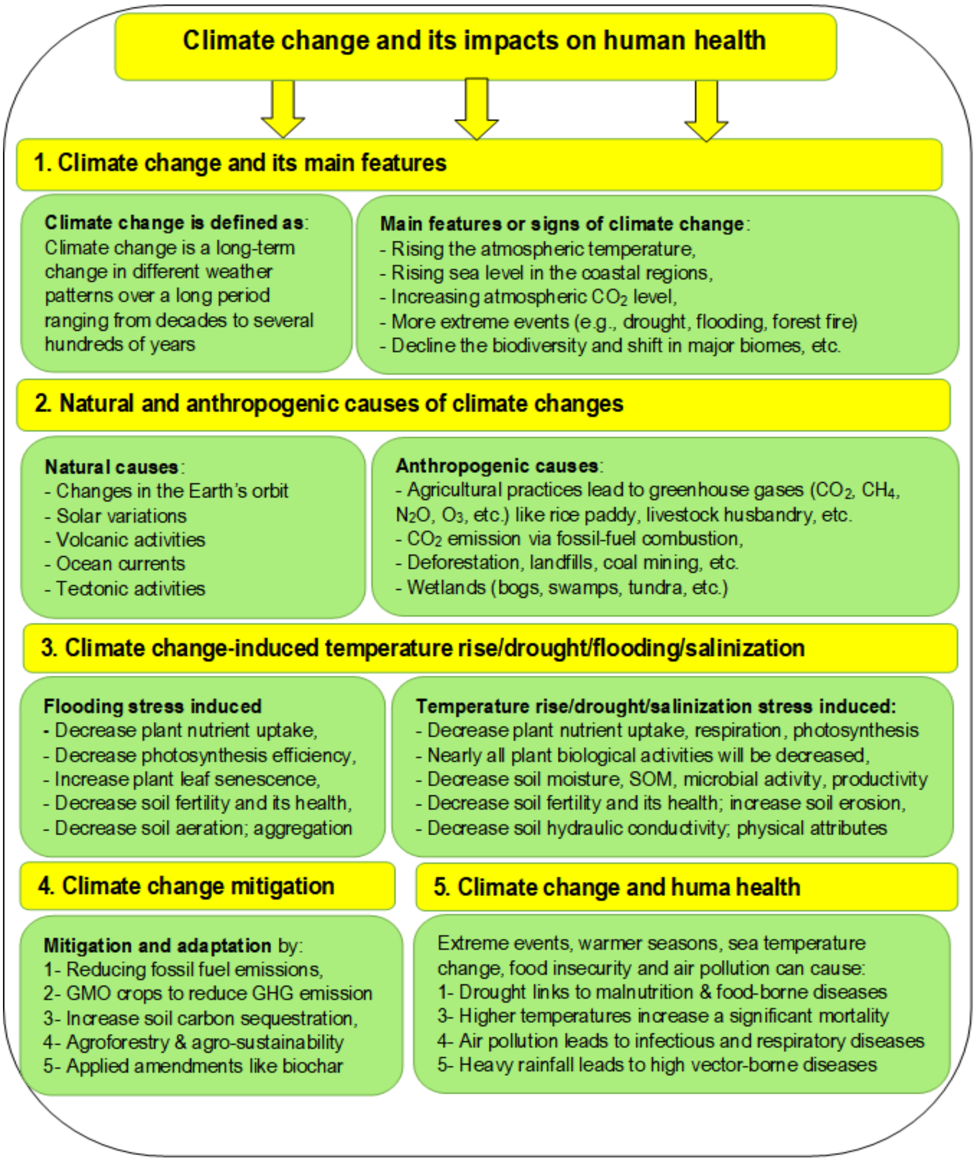


Figure 13. Climate change and its impacts on human health. More details about climate changes and mitigation beyond the impacts of this phenomenon could be noticed. Sources: [6,147,150,153–156].

Ayi et al. [157] showed that alternanthera philoxeroides, or alligator-weed, is a common and often invasive plant that is invasive near waterways and tolerant of flooding. They measured plant growth and root anatomical change in response to varying oxygen or nutrient concentrations in independent hydroponic trials. Results showed root efficiency declined as plants allocated more biomass to roots in response to decreased nutrients, primarily by developing longer, thinner roots, resulting in increased root surface area. Plant responses to lower oxygen concentrations were unexpected; for example, root efficiency was highest at the lowest oxygen concentration. Under low N conditions, Xu et al. [158] found that one rice cultivar, Takanari, maintained its high yielding advantage over other cultivars at increased CO_2. According to the research, this cultivar could be a helpful genetic resource for enhancing N-use efficiency under increased CO_2. In addition, Li et al. [159] investigated the impacts of increased CO_2 on the nutritious content of soybean seeds, while Dong et al. [160] described the findings of a meta-analysis to quantify the effects of increased CO_2 on the nutrient content of other vegetables. Several reports have been published on the role of global climate change in the decline of crop productivity and soil fertility due to the exposure of these soils to many frequent features of climate change such as higher temperatures, droughts, floods, desertification, and salinization resulting from extreme weather events (e.g., [154,161,162]).

Potential climate change and plant bioactive compounds were discussed in a survey, which included some published studies (e.g. [163,164]). The production of plant secondary metabolites (as bioactives) may also depend on climate change, which represents both high temperatures and elevated CO_2 [165]. The expected impact of climate change on plant bioactive compounds is generally negative and may return to the crucial effect of climate on plant productivity as abiotic stress. A high-heat-mediated increase in many plant bioactives (e.g., alkaloids, flavones, and terpenes) has been found in various plant species such as *Catheranthus roseus*, *Quercus rubra*, and *Brassica oleracea* [165]. Recently, a study on the effect of elevated concentrations of CO_2 on the secondary metabolites or bioactive compounds content of different plant species was reported by Lupitu et al. [166]. They found that the contents of total flavonoids and polyphenols were decreased under elevated CO_2 (up to 1200 ppm or µmol mol^{-1}), whereas the emission of monoterpenes increased for the studied *Brassicaceae* plants. This response to elevated CO_2 depends on the studied plant species, as presented in Table 5.

Table 5. Some published studies about effects of changed climatic elements on plant bioactive compounds. All scientific names according to Plants of the World Online (https://powo.science.kew.org/, accessed on 25 June 2022).

Studied Plant	Climate Change Factor	Plant Bioactive Compound and Its Response	Ref.
Purple rice (*Oryza sativa* L.)	Low light intensity	Shading increased total anthocyanin and total phenol compounds	[167]
Catharanthus roseus (L.) G. Don	Ultraviolet-B (UV-B) irradiation for 5 min	Increased alkaloids (catharanthine, vindoline)	[168]
Fagopyrum esculentum Moench	Three treatments of UV-B	Increased phenolics (quercetin, catechi, rutin)	[169]
Gnaphalium luteoalbum L.	Two different levels of irradiance UV-B	Increased phenolics (flavonoids: calycopterin and 3′-methoxycalycopterin)	[170]
Camptotheca acuminata Decne.	Heat stress (from 34 to 46 °C at 2 °C intervals)	Increased alkaloids (10-hydroxycamptothecin)	[171]
Daucus carota L.	Heat stress (incubated at 44 °C)	Decreased terpenoids (α-terpinolene)	[172]
Quercus rubra L.	Heat stress (at 20/14 and 32/24 °C)	Increased terpenoids (isoprene, 2-methyl-1,3-butadiene)	[173]
Daucus carota L.	Heat stress (18 and 21 °C)	Decreased terpinolene (α-terpinolene with increasing growth temperature)	[174]
Dropwort (*Oenanthe stolonifera* L.)	Elevated CO_2 at 600 and 1000 µmol mol^{-1}	Total phenolics/cyanidin/antioxidant capacity of plantlets increased by high eCO_2	[175]
Asparagus racemosus Willd.	Elevated CO_2 400, 600, and 800 µmol mol^{-1}	Elevated CO_2 increased the content of total sugars and proteins in leaves and roots	[152]
Summer savory (*Satureja hortensis* L.)	Elevated CO_2 (620 µmol mol^{-1})	Nutrients (K, Ca, P, Mg) and polyphenols were enhanced by eCO_2 under drought stress	[176]
Caraway (*Carum carvi* L.)	Elevated CO_2 at 400 and 620 µmol mol^{-1}	Higher CO_2 enhanced content of phenolic compounds and flavonoids	[177]
Barley (*Hordeum vulgare* L.) and maize (*Zea mays* L.)	eCO_2 level (620 µmol mol^{-1})	Barley accumulated anthocyanins, but total phenolics and flavonoids accumulated in maize under As_2O_3-NP stress and elevated CO_2	[178]
Two species of lemon-grass	Elevated CO_2 (620 µmol mol^{-1})	eCO_2 increased level of primary and secondary metabolites such as amino acids and phenolics	[179]
Paris polyphylla var. yunnanensis	Elevated CO_2 (800 µmol mol^{-1})	A high-CO_2 environment increased the diosgenin content and thus total saponin	[180]
Glehnia littoralis Fr. Schmidt ex Miquel	Elevated CO_2 (500, 1500 µmol·mol^{-1}) under 3 light intensities	Higher light intensities (300) induced higher content of total saponin and chlorogenic acid, whereas no significant effect from eCO_2	[181]
Tea (*Camellia sinensis* L.)	Elevated CO_2 at 406 and 770 µmol mol^{-1}	Elevated CO_2 significantly increased the polyphenols and theanine in tea seedlings	[182]
Gynostemma pentaphyllum (Thunb.) Makino	Elevated CO_2 at 360 and 720 µmol mol^{-1}	Elevated CO_2 led to decreased accumulation of total phenolics and flavonoids in leaves	[183]

6.2. Plant Nutrition under Pollution

Pollution is considered a global problem facing all countries in the world due to its potential impacts on human health and entire ecosystems (Figure 14). This pollution creates an urgent need for green lungs in different urban parks and general gardens, especially in cities (Figure 15).

Figure 14. Pollution is considered one of the most important problems facing the entire world even in developed or developing countries, especially pollution resulting from human activities such as domestic wastes (sewage sludges), plastic wastes, sludges disposed of into irrigation canals, and other wastes. All photos of different irrigation canals and urban areas from Egypt by El-Ramady.

Pollution does not only affect cultivated plants or human health but also affects the health of the complete ecosystem depending on the kind of pollution, such as microplastic, sewage sludge, electronic wastes, mining wastes, and human wastes [184]. The problems that face plant nutrition under pollution stress may depend on the type of pollutants, their concentration, the medium of pollution (soil, air, water, etc.), and plant species. Cultivated plants in polluted soils are thought to be the primary source of highly hazardous element accumulators, which are classified as accumulator plants, hyper-accumulator plants, and excluder plants based on the content of hazardous materials they absorb. Toxic components could potentially accumulate and spread from soil to plant, water to plant, and air to plant [185]. Therefore, hazardous elements in the polluted environment have a negative impact on plant growth, even at low or high metal concentrations. Toxic elements can harm the photosynthetic process, slow the growth of plants, and cause oxidative stress, and at high concentrations, they can stymie plant growth by interfering with the photosynthetic process and altering the coordination of vital elements and their functional mechanisms [186]. Human activities are the main source for environmental pollution in the context of urbanization and industrialization, which may include pollution from polycyclic aromatic hydrocarbons, heavy metals, polychlorinated biphenyls, pesticides, dioxins, ultrafine particles, etc. [187]. Several studies have shown that almost all biological plant processes impacted by pollution and its criteria, such as photosynthetic rate, plant leaf respiration, protein synthesis, plant metabolic processes, and crop growth, were significantly impacted and destroyed in polluted soils [129,188,189].

Figure 15. Fighting pollution in cities or urban areas may require establishing public gardens and parks as presented in these photos, which represent new lungs for the city to generate the necessary O_2 and remove the CO_2 in the atmosphere. The first and second photos from the top row are from Vienna (Austria), the 3rd and 4th photos are from Debrecen (Hungary), the 5th and 6th photos are from Cairo (Al-Azhar-park, Egypt), and the 7th and 8th photos are from München, left, and Halle Saale, right (Germany). All photos by El-Ramady.

According to previous studies, several cultivated plants are negatively influenced by pollutants such as toxic elements, especially the plants' bioactive compounds (Table 6). It is reported that Cd toxicity (120 mg kg^{-1}) reduced the growth parameters, physiological modifications, antioxidant enzymes, and yield of lettuce plants [190]. More recent studies were published to focus on many human diseases (e.g., the impairment of gonadal development and male fertility) resulting from a polluted human diet. At the global level, there is an urgent need to establish an ideal dietary profile, including different diet patterns, to improve health status and reduce the mortality from different human diseases [187].

The cultivation of plants in soil polluted with heavy metals (HMs) is considered to result in abiotic stress, which forces plants to generate oxygen-free radical species (ROS), causing damage in plants in the following forms: (1) disruption of cell homeostasis, (2) DNA-strand breakage, (3) protein defragmentation, (4) damage in pigments, and (5) plant cell death [191]. Therefore, the accumulation of HMs in plants restricts their growth, impairs their structure, and damages their biochemical and physiological activities as well as bioactive compounds, depending on the kind of HMs, their toxicity, and whether it is chronic. This may lead to permanent damage to many human organs, such as the lungs, brain, kidney, and liver [191]. The growing of plants, particularly medicinal plants, in soil polluted with HMs may impact the biosynthesis of secondary metabolites/bioactives, causing significant changes in the quality and quantity of these bioactive compounds [192,193].

Table 6. Some published studies on abiotic stress, including pollution and its impacts on plant bioactive compounds. All scientific names according to Plants of the World Online (https://powo.science.kew.org/, accessed on 25 June 2022).

Studied Plant	Abiotic Stress Details	Plant Bioactive Compound and Its Response	Ref.
Robinia pseudoacacia L.	Applied Cd at 0.45 and 4.5 mg Cd kg^{-1}	Elevated CO_2 (up to 750 ppm) may promote synthesis of total flavonoids under Cd stress	[194]
Potato (*Solanum tuberosum* L.)	Drought stress by discontinued irrigation for 6 weeks after 88 days planting	No significant effect of drought on phenolic compounds, anthocyanins, or antioxidant activity	[195]
Feverfew (*Tanacetum parthenium* (L.) Sch. Bip.)	Drought stress (irrigation intervals 4, 8, and 12 days as control, moderate, extreme)	Under drought stress, the yield of essential oils decreased by 30%, and phenols and nano-silicon increased plant drought tolerance	[196]
Cistus clusii Dunal	Drought stress (days of drought 15, 30, 50)	Increase phenolics (flavonols, epigallocatechin gallate)	[197]
Crataegus laevigata (Poir.) DC.	Drought (water deficit for 10 days vs. watering daily)	Increase phenolics (chlorogenic acid, (-)-epicatechin)	[198]
Glycine max (L.) Merr.	Drought stress (non-irrigated field)	Increased alkaloids (trigonelline)	[199]
Hypericum brasiliense Choisy	Drought stress (water stress (waterlogging and drought))	Increased terpenoids (betulinic acid)	[200]
Pepper (*Capsicum annuum* L.)	In vitro, supplemented MS with 200 μM $CdCl_2$	ZnO-NPs induced mitigation of Cd-toxicity by increased activity of enzymatic antioxidants	[201]
Giant Juncao (*Pennisetum giganteum* Ten. ex Steud.)	Salt stress (250, 500 mM NaCl)	Salicylic acid mitigated the adverse impacts of salt stress, which decreased flavonoids by enhancing the content of chlorogenic acid	[202]
Brassica nigra L.	Salt stress (100 and 150 mM NaCl)	Salinity enhanced forming of many bioactives e.g., phytosterols, and tocopherols	[203]
Faba bean: *Vicia faba* L.	Salt stress at 150 mM NaCl	Salinity induced accumulation of flavonoids, phenols, and tannins, in response to ZnO-NPs	[204]
Calotropis procera (Aiton)	Salt stress in 3 experiments up to 320 mM NaCl using Petri dishes and hydropriming	Seed priming with thiourea and ascorbic acid increased tolerance to salinity up to 120 mM by increasing phenolic acids (gallic, caffeic, p–coumaric, p–benzoic, and sinapic acid)	[205]
Wheat (*Triticum aestivum* L.)	Salt stress (150 mM)	Priming with 0.12% Cu-chitosan-NP induced an increase in β-carotenoids, total carotenoids	[206]
Catharanthus roseus (L.) G. Don	Cold stress (4 °C) in growth chamber	Decreased alkaloids (vindoline)	[207]
Glycine max (L.) Merr.	Cold stress (10 °C)	Increased phenolics (genistein, daidzein)	[208]
Solanum Lycopersicon L.	Cold stress (6 and 3 °C)	Increased terpenoids (δ-elemene, α-humulene, and β-caryophyllene)	[209]
Withania somnifera (L.) Dunal	Cold stress (4 °C) under controlled environment	Increased terpenoids (withanolide A; withferin A)	[210]
Zea mays L.	Cold stress (10 °C)	Increased phenolics (pelargonidin)	[211]

6.3. Plant Nutrition under Stressful Soil

The relationship between soil and plant is very close due to soil generally being the main growing medium for the plant. The soil and its properties are the main controlling factor in plant growth and development. Any stress on the soil will be also a stress on the cultivated plants that are grown in this soil. The ideal conditions for growing plants in soil include sufficient and proper nutrients for soil fertility, soil aeration, soil health, suitable water irrigation, etc. Stressful soil is soil that has a problem, stress, or obstacle restricting productivity. A problematic soil could be defined as a soil that has a reason for a restriction on its economical cultivation, but it requires a suitable management. These soils may include greenhouse soil in arid regions, saline/alkaline soil, acidic soil, sandy soil, waterlogged soil, calcareous soil, compacted soil, infertile soil, and eroded soil (Figure 16A,B).

(**A**)

Figure 16. *Cont.*

(**B**)

Figure 16. (**A**) Desert soils have different problems, which include eroded soil (upper photos), very low vegetation due to stresses (middle photos), and salinization due to very high evaporation rate (lower photos). Different photos from different places in Egypt (Shalateen, Matrouh, and Siwa) are all by El-Ramady. (**B**) Desert soils have different handling compared to the soils of Delta in Egypt. The upper photos express on salinity and waterlogging problems, whereas the same problems in soils of Delta in Egypt could be noticed in the middle and lower photos, due to the salinization under high soil water table. Different photos from different places in Egypt (Siwa in upper 2 photos and Kafr El-Sheikh in the rest) are all by El-Ramady.

Abiotic and biotic stressors have a significant impact on the production of major crops all over the world. Extreme abiotic conditions such as high and low temperatures, drought, salinity, osmotic stress, extremes of pH, heavy rains, floods, various pathogens, and frost damage all pose serious hazards to plant growth and crop production [212]. Under these environmental stresses, plants generate higher quantities of the plant hormone ethylene or other bioactives (e.g., melatonin) in response to certain environmental challenges, which largely inhibits plant growth and proliferation until the stress is alleviated by lowering ethylene levels [213]. The role of plant bioactives is distinguished under stressful conditions such as carotenoids, ascorbic acid, and flavonoids, which are considered important antioxidants for scavenging reactive oxygen species (ROS).

Among abiotic stresses, drought and salinity can cause serious damage to global food production. Global soil salinity is one of the most serious environmental stresses in agriculture around the world, converting agronomically useful fields into unproductive areas by 1–2% every year in arid and semi-arid zones. Soil salinization has rendered around 7% of the world's land and 20% of its arable land uninhabitable [214]. Salinity has long been known to hinder the growth and development of most plants, resulting in lower yields. Furthermore, salinity causes significant changes in plant growth and metabolism, i.e., physiological, morphological, and biochemical alterations [215]. Drought is another important abiotic stress that has a negative impact on the development and production of most cultivated agricultural crops, particularly in arid and semi-arid areas. Drought stress, along with climate change, which causes more severe and frequent droughts, is anticipated to produce serious plant growth issues for more than half of arable areas by 2050 [216]. Furthermore, drought stress affects water relations, photosynthetic assimilation, and nutrient uptake in essential field crops, causing severe effects on plant development and metabolic activities. The nutritional imbalance of minerals limits plant growth and development in poor soils rich in nutrients [217].

Soil salinization, competitive ion uptake, and transport or partitioning of ions within the plant are some of the negative consequences of nutritional imbalances, which can occur when a nutrient's physiological role is deactivated, resulting in an increase in the internal plant requirement for that particular essential element [214]. A considerable amount of nutrients are unavailable to plants due to soil binding organic and mineral components and the production of insoluble precipitates. Plant fitness can be harmed by essential element imbalances due to their impacts on plant nutrition and water absorption, as well as their toxic effects on plant cells [218]. Management of stressful soil could be achieved through different approaches such as soil conservation (biological methods including manures, green manure, water hyacinth, and selecting salt-tolerant varieties) and agronomic approaches such as tillage and improving irrigation, drainage, and fertilizers (Figure 17), as reported by [219].

Figure 17. Different cases for management of plant nutrition, which include, in the upper photos, using plastic mulching, even in an open field or in a greenhouse; in the middle, collecting the fall leaves from

deciduous trees during the autumn to make compost as an important organic fertilizer; and at the bottom, cultivation of paddy rice under soil salinity as an important strategy to reclaim this soil salinity. All photos from Debrecen (Hungary), Göttingen (Germany), and Kafr El-Sheikh (Egypt) by El-Ramady.

Concerning the impact of abiotic stresses on plant bioactives, many stresses have been presented in Table 6, such as drought, salinity, element toxicity, and cold stress. In general, there is no one trend for this relationship, but some stresses increase the content of the bioactives, whereas others do the opposite. For example, some stressful plants tend to increase plant content of bioactives under drought, such as *Cistus clusii* (increased phenolics or flavonols), *Tanacetum parthenium* (decreased phenols), *Crataegus laevigata Glycine max*), and *Hypericum brasiliense*, which increased the previous content of phenolics, alkaloids, and terpenoids under drought, respectively. More problematic soils and bioactive compounds and more details on the plant bioactives cultivated as a response to abiotic stress are explained in Table 6.

7. General Discussion

The chemistry of bioactive compounds is an important field, which includes those chemical compounds derived from microbes and plant sources. It is well known that microbes and plants are the main sources of natural bioactives, which are used for numerous applications in different disciplines such as plant biotechnology, pharmacology, and phytomedicine. The most important issue in the field of bioactive compounds may be its potential to discover of several potent drugs that combat both plant and human diseases [193]. The main groups of plant bioactives may include alkaloids, flavonoids, saponins, tannins, and glycosides, which differ from one plant species to another. The most interesting finding is that plant secondary metabolites or bioactives have the ability to protect plants, and stressful plants can generate these bioactives as a response to different abiotic stresses. Furthermore, these bioactives simultaneously have great potential for pharmaceutical products for human health [220].

The present review was designed to study the bioactive compounds in plants as among the main plant components for human health, their main groups, and the impacts of different stresses on their forming in plants. This section discusses the major groups of plant bioactives, the main role (mechanism) of these bioactives in plants under stress, and their medicinal attributes. It is reported that globally, more than 200,000 plant secondary metabolites (bioactives) have been identified, from more than 391,000 well-known plant species [220]. Plant bioactives have certain biochemical and physiological functions in plants, which support plant growth and development, especially under stressful conditions, as well as clinical attributes for human health. Plant bioactives could be classified into three main groups, based on their chemical structure and biosynthetic pathway: (1) phenolic compounds (flavonoids, coumarins, phenolic acids, lignans, lignin, stilbenes, and tannins), (2) N-containing compounds (alkaloids, cyanogenic glycosides, and glucosinolates), and (3) terpenoids (carotenoids, glycosides, sterols, saponins, and plant volatiles) [221–223]. Plants are different in their content of bioactives due to their genetic variability, but their contents are influenced by several factors, including environmental growth conditions as well as climate change (e.g., drought, heat stress, O_3, and UV radiation), pathogens, and herbivore attacks [220].

Concerning the group of terpenoids, it could be classified into monoterpenoids (e.g., linalool), sesquiterpenoids (β-caryophyllene), diterpenoids (abietic acid), sesterterpenoids (ophiobolin A), triterpenoids (ganoderic acid), tetraterpenoids (α-carotene), and polyterpenoids (trans-1,4-polyisoprene). This group is characterized as plant hormones (such as gibberellins), photosynthetic pigments (such as carotenoids), and carriers (such as plastoquinone and ubiquinone) in the electron chain transport systems [220]. The mechanism of terpenoids in protecting after plants are attacked by pathogens may include directly releasing phytoalexins or acting indirectly by producing volatile organic compounds to attract herbivores [186]. Several terpenoids have antioxidant activities against biotic/abiotic stresses in plants, in addition to their pharmacological effects in several folk medicinal plants due to their antimicrobial activity [224].

Regarding phenolic compounds from plants, more than 8000 compounds are well-reported, where more than half of them are flavonoids. Phenolics could be divided, based on their diverse structures, into (1) aromatic rings (e.g., caffeic acid, ferulic acid, gentisic acid, and vanillin) and (2) complex polymeric structures such as coumarins (such as scopoletin), flavonoids, phenolic quinones (juglone), lignins (coniferyl alcohol), and tannins (ellagic acid) [225]. Under extreme cold or heat, flavonoids trend towards increasing their accumulation in plants. Chandran et al. [18] reported on the bioactives in 39 medicinal plants and their applications in therapeutic activities. They mentioned that certain phenols (alkaloids, flavonoids, saponins, steroids, tannins, and triterpenoids) could be found in *Chlorophytum borivilianum* plants as effective agents of aphrodisiac, pro-erectile, immunomodulatory, spermatogenic, anti-stress, and anti-oxidant activities. *Carthamus tinctorius* has many bioactives such as alkaloids, flavonoids, phenolics, lignans, steroids, and polysaccharides, which could be applied for therapeutic activities such as treating cardiovascular, cerebrovascular, and gynecological diseases, as well as antioxidant and anticoagulant effects [18].

There are more than 20,000 alkaloids that have been isolated, among which about 600 are well-known to be bioactives, but the exact metabolic or physiological role of alkaloids in plants still needs to be understood [226]. Alkaloids are considered a main group of plant molecules for defense, which might occur in about 20% of plant species and have N-atom(s) derived from the decarboxylation of amino acid [220]. Based on therapeutical activities, alkaloids are well-known as cardioprotective, anesthetics, and anti-inflammatory agents, as well as for their use in clinical settings such as ephedrine, morphine, quinine, strychnine, and nicotine [227].

Plant tissue culture is considered a promising tool and a perpetual source for producing plant bioactive compounds, as reported by several studies, such as Espinosa-Leal et al. [228], Chandran et al. [18], Arora et al. [229], Fazili et al. [88], and Mishra et al. [230]. Many methods could be employed for producing plant bioactives on a large scale, such as using plant in vitro tissue culture through organogenesis (including both micropropagation and hairy root culture) or cell suspension culture using callogenesis [228]. This technique remains a feasible strategy for the production of plant bioactives and high-value natural materials and micropropagation of underexploited, endangered, low-yielding, or slow-growing plants. Many significant advantages of this technique have been reported for producing plant bioactives and pharmaceuticals, such as rapid production, reduced costs, low burden of human pathogens, and scalability [228]. The composition of used medium and kinds of elicitors can control the production of plant bioactives in vitro (Table 7).

Table 7. List of some published studies on the production of plant bioactives using the in vitro plant tissue culture technique.

Studied Plant	Bioactive Product(s)	The Most Important Finding in the Study	Ref.
Nothapodytes nimmoniana (J. Graham) Mabb.	Camptothecin (CPT)	Cell suspension culture using 5 biotic elicitors (i.e., chitin, chitosan, glutathione, pullulan, and jasmonic acid); the best was chitin (11.48-fold)	[231]
Taxus × *media* Rehder	Paclitaxel (PTX)	Cell culture: using coronatine and calix [8]-arenes as an elicitor to produce PTX as an anticancer agent	[232]
Chinaberry (*Melia Azedarach* L.)	Limonoid	Cell suspension culture for production of bioactive was highest by 141.7 µg/ml	[233]
Neem (*Azadirachta indica* A. Juss.)	Azadirachtin, squalene, and mevalonic acid	Cell suspension culture using chitosan and yeast extract as elicitors; bioactives depended on the used elicitor	[234]

Table 7. *Cont.*

Studied Plant	Bioactive Product(s)	The Most Important Finding in the Study	Ref.
Neem (*Azadirachta indica* A. Juss.)	Azadirachtin, squalene, and mevalonic acid	Cell suspension culture: bioactives depended on response surface methodology (i.e., central composite design and Box–Behnken design)	[235]
Salvia leriifolia Benth.	Phenolic acids: cafeic and salvianolic acid B	Cell cultures for max. production of cafeic and salvianolic acid B at the 15th day of the cultivation cycle	[236]
Neem (*Azadirachta indica* A. Juss.)	Azadirachtin and squalene	Callus culture: PGRs (TDZ and 2,4-D) promoted accumulation and the color of bioactives	[237]
Taxus baccata L.	Taxanes (paclitaxel and 10-deacetyl baccatin III)	Callus culture: under drought stress (PEG 6000 1, 2, 3, 4, 6%), highest contents of 10-deacetyl baccatin III and taxol at 2 and 3% PEG, resp.	[238]
Withania somnifera L. Dunal	Withaferin-A	Hairy root culture using *A. rhizogenes* and natural polysaccharides (as elicitors)	[239]
Brassica rapa subsp. pekinensis (Lour.) Kitam.	Glucosinolates (GLS) and carotenoid (CAR)	Hairy root culture: total GSL, CAR content was 2.7–57.88 μmol/g DW and 467.66 mg kg^{-1} DW, respectively	[240]
Hyoscyamus reticulatus L	Tropane alkaloids: (hyoscyamine and scopolamine)	Hairy root culture using *A. rhizogenes* and elicited by Fe_3O_4-NPs at different doses (0.45, 0.9, 1.8, and 3.6 g L^{-1})	[241]
Flax (*Linum usitatissimum* L.)	Lignan (e.g., secoiso-lariciresinol diglucoside)	Hairy root culture using *A. rhizogenes*, which had an inhibition effect on the proliferation of human breast cancer under cell line	[242]

Concerning the photographic approach, many pictorial published articles have recently been issued on different topics, including management of salt-affected soils [243], soil and humans [244], the soil–water–plant–human nexus [245], and a from-farm-to-fork approach using nanofarming of vegetables [246].

8. Conclusions

This study has discussed the relationship between plant nutrition and human health. This work set out to review in detail the available information on plant nutrition through plants' bioactive compounds and human health under the umbrella of sustainable agriculture. This is a pictorial review, as a first report, which was established using the available photos or drawn illustrated figures, to follow different factors affecting the production of plant bioactives, including climate change (elevated CO_2, drought, heat stress, etc.) and environmental factors (e.g., polluted, degraded, and problematic soils). The main groups of plant bioactives that were reported in this work included phenolic compounds, N-containing compounds (alkaloids, cyanogenic glycosides, and glucosinolates), and terpenoids. The plant content of these bioactives may increase under stressful conditions as a defense system in plants. Plant tissue culture is considered a promising tool in producing several plant bioactives, especially in cases of underexploited or endangered plants. The observed increase in plant bioactives could be attributed to the existence of some findings under in vitro conditions. These findings have significant implications for the understanding of how to produce huge amounts of plant bioactives successfully, especially in cases of normal medicinal or endangered plants. Agricultural technology (agro-technics) has several applications or techniques that could be used to manage and improve almost all agricultural practices, such as fertilization, irrigation, harvesting, and plant tissue culture. These findings also raise important global issues that have a bearing on the importance of edible and medicinal plants for human health and their therapeutical activities. Due to the huge number of plant bioactives and their broad potential for human health, further investigation into and experimentation with plant bioactives are strongly recommended.

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References

1. Stratton, A.E.; Kuhl, L.; Blesh, J. Ecological and Nutritional Functions of Agroecosystems as Indicators of Smallholder Resilience. *Front. Sustain. Food Syst.* **2020**, *4*, 543914. [CrossRef]
2. Goncharova, N.A.; Merzlyakova, N.V. Food Shortages and Hunger as a Global Problem. *Food Sci. Technol.* **2022**, *42*, e70621. [CrossRef]
3. Bang, T.C.; Husted, S.; Laursen, K.H.; Persson, D.P.; Schjoerring, J.K. The Molecular–Physiological Functions of Mineral Macronutrients and Their Consequences for Deficiency Symptoms in Plants. *New Phytol.* **2021**, *229*, 2446–2469. [CrossRef]
4. Roberts, D.P.; Mattoo, A.K. Sustainable Crop Production Systems and Human Nutrition. *Front. Sustain. Food Syst.* **2019**, *3*, 72. [CrossRef]
5. Cakmak, I. Plant Nutrition Research: Priorities to Meet Human Needs for Food in Sustainable Ways. *Plant Soil* **2002**, *247*, 3–24. [CrossRef]
6. Elbasiouny, H.; El-Ramady, H.; Elbehiry, F.; Rajput, V.D.; Minkina, T.; Mandzhieva, S. Plant Nutrition under Climate Change and Soil Carbon Sequestration. *Sustainability* **2022**, *14*, 914. [CrossRef]
7. Moses, T.; Goossens, A. Plants for Human Health: Greening Biotechnology and Synthetic Biology. *J. Exp. Bot.* **2017**, *68*, 4009–4011. [CrossRef]
8. Bruulsema, T.; Cakmak, I.; Dobermann, A.; Gerard, B.; Majumdar, K.; McLaughlin, M.; Reidsma, P.; Vanlauwe, B.; Wollenberg, E.K.; Zhang, F.; et al. Scientific Panel on Responsible Plant Nutrition. A New Paradigm for Plant Nutrition. Issue Brief 01. Available online: https://www.apni.net/downloads/sprpnIss01.pdf (accessed on 4 April 2022).
9. Kumar, V.; Srivastava, A.; Suprasanna, P. *Plant Nutrition and Food Security in the Era of Climate Change*; Academic Press: Oxford, UK; Elsevier: Amsterdam, The Netherlands, 2022.
10. Perrino, E.V.; Valerio, F.; Jallali, S.; Trani, A.; Mezzapesa, G.N. Ecological and Biological Properties of Satureja Cuneifolia Ten. and Thymus Spinulosus Ten.: Two Wild Officinal Species of Conservation Concern in Apulia (Italy). A Preliminary Survey. *Plants* **2021**, *10*, 1952. [CrossRef]
11. Valerio, F.; Mezzapesa, G.N.; Ghannouchi, A.; Mondelli, D.; Logrieco, A.F.; Perrino, E.V. Characterization and Antimicrobial Properties of Essential Oils from Four Wild Taxa of Lamiaceae Family Growing in Apulia. *Agronomy* **2021**, *11*, 1431. [CrossRef]
12. Perrino, E.V.; Wagensommer, R.P. Crop Wild Relatives (CWRs) Threatened and Endemic to Italy: Urgent Actions for Protection and Use. *Biology* **2022**, *11*, 193. [CrossRef]
13. Larson-Meyer, E.D.; Ruscigno, M. *Plant-Based Sports Nutrition: Expert Fueling Strategies for Training, Recovery, and Performance*, 1st ed.; Human Kinetics: Champaign, IL, USA, 2020.
14. Masoodi, M.H.; Rehman, M.U. *Edible Plants in Health and Diseases: Volume 1: Cultural, Practical and Economic Value*; Springer Nature: Singapore, 2022; ISBN 9789811648793.
15. Masoodi, M.H.; Rehman, M.U. *Edible Plants in Health and Diseases: Volume II: Phytochemical and Pharmacological Properties*; Springer: Singapore, 2022; ISBN 9789811649585.
16. Savage, E. *Healing Through Nutrition: The Essential Guide to 50 Plant-Based Nutritional Sources*; ROCKRIDGE Press: Emeryville, CA, USA, 2020; ISBN 978-1-64152-813-9.
17. Summer, E. Plant-based high-protein diet: The Athletes Nutrition Guide with Easy Recipes to Burn Fat. In *How to Use Vegetable-Based Protein and Boost Energy for Muscle Growth and Athletic Performance Improvement*; Independently Published: Chicago, IL, USA, 2020; ISBN 9798628313237.

18. Chandran, H.; Meena, M.; Barupal, T.; Sharma, K. Plant Tissue Culture as a Perpetual Source for Production of Industrially Important Bioactive Compounds. *Biotechnol. Rep.* **2020**, *26*, e00450. [CrossRef] [PubMed]
19. Gai, Q.-Y.; Lu, Y.; Jiao, J.; Fu, J.-X.; Xu, X.-J.; Yao, L.; Fu, Y.-J. Application of UV-B Radiation for Enhancing the Accumulation of Bioactive Phenolic Compounds in Pigeon Pea [*Cajanus Cajan* (L.) Millsp.] Hairy Root Cultures. *J. Photochem. Photobiol. B* **2022**, *228*, 112406. [CrossRef] [PubMed]
20. Mohd Zaini, H.; Roslan, J.; Saallah, S.; Munsu, E.; Sulaiman, N.S.; Pindi, W. Banana Peels as a Bioactive Ingredient and Its Potential Application in the Food Industry. *J. Funct. Foods* **2022**, *92*, 105054. [CrossRef]
21. Paulo, F.; Tavares, L.; Santos, L. Extraction and Encapsulation of Bioactive Compounds from Olive Mill Pomace: Influence of Loading Content on the Physicochemical and Structural Properties of Microparticles. *J. Food Meas. Charact.* **2022**. [CrossRef]
22. Patil, S.; Vedashree, M.; Murthy, P.S. Valorization of Coffee Leaves as a Potential Agri-Food Resource: Bio-Active Compounds, Applications and Future Prospective. *Planta* **2022**, *255*, 67. [CrossRef]
23. Fageria, N.K. Soil Fertility and Plant Nutrition Research under Controlled Conditions: Basic Principles and Methodology. *J. Plant Nutr.* **2005**, *28*, 1975–1999. [CrossRef]
24. Fageria, N.K. Soil Fertility and Plant Nutrition Research under Field Conditions: Basic Principles and Methodology. *J. Plant Nutr.* **2007**, *30*, 203–223. [CrossRef]
25. El-Ramady, H.R.; Alshaal, T.A.; Shehata, S.A.; Domokos-Szabolcsy, É.; Elhawat, N.; Prokisch, J.; Fári, M.; Marton, L. Plant Nutrition: From Liquid Medium to Micro-Farm. In *Sustainable Agriculture Reviews 14*; Ozier-Lafontaine, H., Lesueur-Jannoyer, M., Eds.; Sustainable Agriculture Reviews; Springer International Publishing: Cham, Switzerland, 2014; Volume 14, pp. 449–508. ISBN 978-3-319-06015-6.
26. Barbosa, W.L.R.; Nascimento, M.S.; do Pinto, L.N.; Maia, F.L.C.; Sousa, A.J.A.; Júnior, J.O.C.S.; Monteiro, M.M.; de Oliveira, D.R. *Selecting Medicinal Plants for Development of Phytomedicine and Use in Primary Health Care*; InTech Open: Rijeka, Croatia, 2012; ISBN 978-953-307-805-2.
27. United Nations Sustainable Development Goals. Sustainable Development Knowledge Platform. Available online: https://sustainabledevelopment.un.org/sdgs (accessed on 20 April 2022).
28. Dordas, C. Role of Nutrients in Controlling Plant Diseases in Sustainable Agriculture: A Review. In *Sustainable Agriculture*; Lichtfouse, E., Navarrete, M., Debaeke, P., Véronique, S., Alberola, C., Eds.; Springer: Dordrecht, The Netherlands, 2009; pp. 443–460. ISBN 978-90-481-2665-1.
29. Isaac, W.-A.; Felix, N.; Ganpat, W.G.; Saravanakumar, D.; Churaman, J. Sustainable Climate-Smart Agricultural Solutions to Improve Food and Nutrition Security in Trinidad and Tobago. In *Development, Political, and Economic Difficulties in the Caribbean*; Bissessar, A.M., Ed.; Springer International Publishing: Cham, Switzerland, 2019; pp. 167–195. ISBN 978-3-030-02993-7.
30. Babu, S.; Singh, R.; Yadav, D.; Rathore, S.S.; Raj, R.; Avasthe, R.; Yadav, S.K.; Das, A.; Yadav, V.; Yadav, B.; et al. Nanofertilizers for Agricultural and Environmental Sustainability. *Chemosphere* **2022**, *292*, 133451. [CrossRef]
31. Elemike, E.E.; Uzoh, I.M.; Onwudiwe, D.C.; Babalola, O.O. The Role of Nanotechnology in the Fortification of Plant Nutrients and Improvement of Crop Production. *Appl. Sci.* **2019**, *9*, 499. [CrossRef]
32. Agrawal, S.; Kumar, V.; Kumar, S.; Shahi, S.K. Plant Development and Crop Protection Using Phytonanotechnology: A New Window for Sustainable Agriculture. *Chemosphere* **2022**, *299*, 134465. [CrossRef]
33. Cappelli, S.L.; Domeignoz-Horta, L.A.; Loaiza, V.; Laine, A.-L. Plant Biodiversity Promotes Sustainable Agriculture Directly and via Belowground Effects. *Trends Plant Sci.* **2022**, *27*, 674–687. [CrossRef] [PubMed]
34. Ditta, A.; Arshad, M. Applications and Perspectives of Using Nanomaterials for Sustainable Plant Nutrition. *Nanotechnol. Rev.* **2016**, *5*, 209–229. [CrossRef]
35. Perea Vélez, Y.S.; Carrillo-González, R.; González-Chávez, M. Interaction of Metal Nanoparticles–Plants–Microorganisms in Agriculture and Soil Remediation. *J. Nanopart. Res.* **2021**, *23*, 206. [CrossRef]
36. Bahrulolum, H.; Nooraei, S.; Javanshir, N.; Tarrahimofrad, H.; Mirbagheri, V.S.; Easton, A.J.; Ahmadian, G. Green Synthesis of Metal Nanoparticles Using Microorganisms and Their Application in the Agrifood Sector. *J. Nanobiotechnol.* **2021**, *19*, 86. [CrossRef] [PubMed]
37. Koopaee, H.K.; Rezaei, V.; Esmailizadeh, A. DNA Biosensors Techniques and Their Applications in Food Safety, Environmental Protection and Biomedical Research: A Mini-Review. *J. Cell Dev. Biol.* **2020**, *3*, 28–35. [CrossRef]
38. García-Aljaro, C.; Bangar, M.A.; Baldrich, E.; Muñoz, F.J.; Mulchandani, A. Conducting Polymer Nanowire-Based Chemiresistive Biosensor for the Detection of Bacterial Spores. *Biosens. Bioelectron.* **2010**, *25*, 2309–2312. [CrossRef]
39. Sun, Y.; Fang, L.; Wan, Y.; Gu, Z. Pathogenic Detection and Phenotype Using Magnetic Nanoparticle-Urease Nanosensor. *Sens. Actuators B Chem.* **2018**, *259*, 428–432. [CrossRef]
40. Podar, D.; Maathuis, F.J.M. Primary Nutrient Sensors in Plants. *iScience* **2022**, *25*, 104029. [CrossRef]
41. Marles, R.J. Mineral Nutrient Composition of Vegetables, Fruits and Grains: The Context of Reports of Apparent Historical Declines. *J. Food Compos. Anal.* **2017**, *56*, 93–103. [CrossRef]
42. Wang, J.; Liu, F.; Li, J.; Huang, K.; Yang, X.; Chen, J.; Liu, X.; Cao, J.; Chen, S.; Shen, C.; et al. Fruit and Vegetable Consumption, Cardiovascular Disease, and All-Cause Mortality in China. *Sci. China Life Sci.* **2022**, *65*, 119–128. [CrossRef]
43. Bharali, B.; Chetia, H.; Kalita, J.J.; Mosahari, P.V.; Chhillar, A.K.; Bora, U. Engineered Nanomaterials in Plants: Sensors, Carriers, and Bio-Imaging. In *Comprehensive Analytical Chemistry*; Elsevier: Amsterdam, The Netherlands, 2019; Volume 87, pp. 133–157. ISBN 978-0-12-821320-9.

44. Karthika, K.S.; Rashmi, I.; Parvathi, M.S. Biological Functions, Uptake and Transport of Essential Nutrients in Relation to Plant Growth. In *Plant Nutrients and Abiotic Stress Tolerance*; Hasanuzzaman, M., Fujita, M., Oku, H., Nahar, K., Hawrylak-Nowak, B., Eds.; Springer: Singapore, 2018; pp. 1–49. ISBN 978-981-10-9043-1.
45. White, P.J.; Brown, P.H. Plant Nutrition for Sustainable Development and Global Health. *Ann. Bot.* **2010**, *105*, 1073–1080. [CrossRef] [PubMed]
46. Bhattacharya, A. Mineral Nutrition of Plants under Soil Water Deficit Condition: A Review. In *Soil Water Deficit and Physiological Issues in Plants*; Springer: Singapore, 2021; pp. 287–391. ISBN 978-981-336-275-8.
47. Rattan, R. Mineral Nutrition of Plants. In *Soil Science: An Introduction*; Rattan, R.K., Katyal, J.C., Dwivedi, B.S., Sarkar, A.K., Bhattacharyya, T., Tarafdar, J.C., Kukal, S.S., Eds.; Indian Society of Soil Science: New Delhi, India, 2015.
48. Amtmann, A.; Armengaud, P. Effects of N, P, K and S on Metabolism: New Knowledge Gained from Multi-Level Analysis. *Curr. Opin. Plant Biol.* **2009**, *12*, 275–283. [CrossRef] [PubMed]
49. Taiz, L.; Zeiger, E. Mineral Nutrition. In *Plant Physiology*, 3rd ed.; Sinauer Publishers: Sunderland, MA, USA, 2002.
50. Mengel, K.; Kirkby, E.A. Principles of Plant Nutrition, 5th Edn. Rashtriya Printers, Delhi, First Indian Reprint. *Ann. Bot.* **2006**, *93*, 479–480. [CrossRef]
51. Maathuis, F.J. Physiological Functions of Mineral Macronutrients. *Curr. Opin. Plant Biol.* **2009**, *12*, 250–258. [CrossRef] [PubMed]
52. Hänsch, R.; Mendel, R.R. Physiological Functions of Mineral Micronutrients (Cu, Zn, Mn, Fe, Ni, Mo, B, Cl). *Curr. Opin. Plant Biol.* **2009**, *12*, 259–266. [CrossRef]
53. Kusunoki, M. Mono-Manganese Mechanism of the Photosytem II Water Splitting Reaction by a Unique Mn4Ca Cluster. *Biochim. Biophys. Acta BBA-Bioenerg.* **2007**, *1767*, 484–492. [CrossRef]
54. Broschat, T. Iron Deficiency in Palms. Available online: https://edis.ifas.ufl.edu/publication/EP265 (accessed on 31 May 2022).
55. Lui, G.; Simonne, E.; Li, Y. Nickel Nutrition in Plants. HS1191 UF/IFAS Extension. Available online: https://edis.ifas.ufl.edu/publication/HS1191 (accessed on 31 May 2022).
56. Hebbern, C.A.; Laursen, K.H.; Ladegaard, A.H.; Schmidt, S.B.; Pedas, P.; Bruhn, D.; Schjoerring, J.K.; Wulfsohn, D.; Husted, S. Latent Manganese Deficiency Increases Transpiration in Barley (*Hordeum vulgare*). *Physiol. Plant.* **2009**, *135*, 307–316. [CrossRef]
57. Chanu, N.B.; Alice, A.K.; Thokchom, A.; Singh, M.C.; Chanu, N.T.; Singh, Y.D. Engineered Nanomaterial and Their Interactions with Plant–Soil System: A Developmental Journey and Opposing Facts. *Nanotechnol. Environ. Eng.* **2021**, *6*, 36. [CrossRef]
58. Morgan, J.B.; Connolly, E.L. Plant-Soil Interactions: Nutrient Uptake. *Nat. Educ. Knowl.* **2013**, *4*, 2.
59. Lesellier, E.; Lefebvre, T.; Destandau, E. Recent Developments for the Analysis and the Extraction of Bioactive Compounds from *Rosmarinus Officinalis* and Medicinal Plants of the Lamiaceae Family. *TrAC Trends Anal. Chem.* **2021**, *135*, 116158. [CrossRef]
60. Ahmed, F. Antioxidant Activity of Ricinus Communis. *Org. Med. Chem. Int. J.* **2018**, *5*, 107–112. [CrossRef]
61. de la Luz Cádiz-Gurrea, M.; Sinan, K.I.; Zengin, G.; Bene, K.; Etienne, O.K.; Leyva-Jiménez, F.J.; Fernández-Ochoa, Á.; del Carmen Villegas-Aguilar, M.; Mahomoodally, M.F.; Lobine, D.; et al. Bioactivity Assays, Chemical Characterization, ADMET Predictions and Network Analysis of *Khaya Senegalensis* A. Juss (Meliaceae) Extracts. *Food Res. Int.* **2021**, *139*, 109970. [CrossRef]
62. Sinan, K.I.; Martinović, L.S.; Peršurić, Ž.; Pavelić, S.K.; Etienne, O.K.; Mahomoodally, M.F.; Sadeer, N.B.; Zengin, G. Novel Insights into the Biopharmaceutical Potential, Comparative Phytochemical Analysis and Multivariate Analysis of Different Extracts of Shea Butter Tree-*Vitellaria Paradoxa* C. F. Gaertn. *Process Biochem.* **2020**, *98*, 65–75. [CrossRef]
63. Tlili, N.; Sarikurkcu, C. Bioactive Compounds Profile, Enzyme Inhibitory and Antioxidant Activities of Water Extracts from Five Selected Medicinal Plants. *Ind. Crops Prod.* **2020**, *151*, 112448. [CrossRef]
64. Knez Hrnčič, M.; Cör, D.; Simonovska, J.; Knez, Ž.; Kavrakovski, Z.; Rafajlovska, V. Extraction Techniques and Analytical Methods for Characterization of Active Compounds in Origanum Species. *Molecules* **2020**, *25*, 4735. [CrossRef] [PubMed]
65. Chassagne, F.; Samarakoon, T.; Porras, G.; Lyles, J.T.; Dettweiler, M.; Marquez, L.; Salam, A.M.; Shabih, S.; Farrokhi, D.R.; Quave, C.L. A Systematic Review of Plants with Antibacterial Activities: A Taxonomic and Phylogenetic Perspective. *Front. Pharmacol.* **2021**, *11*, 586548. [CrossRef]
66. Rai, M.; Kosalec, I. *Promising Antimicrobials from Natural Products*; Springer International Publishing: Cham, Switzerland, 2022; ISBN 978-3-030-83503-3.
67. Maran, S.; Yeo, W.W.Y.; Lim, S.-H.E.; Lai, K.-S. Plant Secondary Metabolites for Tackling Antimicrobial Resistance: A Pharmacological Perspective. In *Antimicrobial Resistance*; Kumar, V., Shriram, V., Paul, A., Thakur, M., Eds.; Springer Nature Singapore: Singapore, 2022; pp. 153–173. ISBN 9789811631191.
68. Anand, S.; Bharadvaja, N. Potential Benefits of Nutraceuticals for Oxidative Stress Management. *Rev. Bras. Farmacogn.* **2022**, *32*, 211–220. [CrossRef]
69. Iyer, A.; Guerrier, L.; Leveque, S.; Bestwick, C.S.; Duncan, S.H.; Russell, W.R. High Throughput Method Development and Optimised Production of Leaf Protein Concentrates with Potential to Support the Agri-Industry. *J. Food Meas. Charact.* **2022**, *16*, 49–65. [CrossRef]
70. Stangoulis, J.C.R.; Knez, M. Biofortification of Major Crop Plants with Iron and Zinc-Achievements and Future Directions. *Plant Soil* **2022**, *474*, 57–76. [CrossRef]
71. DeClercq, V.; Nearing, J.T.; Sweeney, E. Plant-Based Diets and Cancer Risk: What Is the Evidence? *Curr. Nutr. Rep.* **2022**, *11*, 354–369. [CrossRef]
72. Setapar, S.; Ahmad, A.; Jawaid, M. *Nanotechnology for the Preparation of Cosmetics Using Plant-Based Extracts. A Volume in Micro and Nano Technologies*; Elsevier: Amsterdam, The Netherlands, 2022; ISBN 978-0-12-822967-5.

73. Ugoeze, K.C.; Odeku, O.A. Herbal Bioactive–Based Cosmetics. In *Herbal Bioactive-Based Drug Delivery Systems*; Elsevier: Amsterdam, The Netherlands, 2022; pp. 195–226. ISBN 978-0-12-824385-5.
74. Reque, P.M.; Brandelli, A. Encapsulation of Probiotics and Nutraceuticals: Applications in Functional Food Industry. *Trends Food Sci. Technol.* **2021**, *114*, 1–10. [CrossRef]
75. Ducrocq, M.; Morel, M.-H.; Anton, M.; Micard, V.; Guyot, S.; Beaumal, V.; Solé-Jamault, V.; Boire, A. Biochemical and Physical–Chemical Characterisation of Leaf Proteins Extracted from *Cichorium Endivia* Leaves. *Food Chem.* **2022**, *381*, 132254. [CrossRef] [PubMed]
76. Manickavasagan, A.; Lim, L.-T.; Ali, A. *Plant Protein Foods*; Springer International Publishing: Cham, Switzerland, 2022; ISBN 978-3-030-91205-5.
77. Santamaría-Fernández, M.; Lübeck, M. Production of Leaf Protein Concentrates in Green Biorefineries as Alternative Feed for Monogastric Animals. *Anim. Feed Sci. Technol.* **2020**, *268*, 114605. [CrossRef]
78. Ewy, M.W.; Patel, A.; Abdelmagid, M.G.; Mohamed Elfadil, O.; Bonnes, S.L.; Salonen, B.R.; Hurt, R.T.; Mundi, M.S. Plant-Based Diet: Is It as Good as an Animal-Based Diet When It Comes to Protein? *Curr. Nutr. Rep.* **2022**, *11*, 337–346. [CrossRef]
79. Joshi, S.; McMacken, M.; Kalantar-Zadeh, K. Plant-Based Diets for Kidney Disease: A Guide for Clinicians. *Am. J. Kidney Dis. Off. J. Natl. Kidney Found.* **2021**, *77*, 287–296. [CrossRef]
80. Kalyniukova, A.; Holuša, J.; Musiolek, D.; Sedlakova-Kadukova, J.; Płotka-Wasylka, J.; Andruch, V. Application of Deep Eutectic Solvents for Separation and Determination of Bioactive Compounds in Medicinal Plants. *Ind. Crops Prod.* **2021**, *172*, 114047. [CrossRef]
81. Atanasov, A.G.; Waltenberger, B.; Pferschy-Wenzig, E.-M.; Linder, T.; Wawrosch, C.; Uhrin, P.; Temml, V.; Wang, L.; Schwaiger, S.; Heiss, E.H.; et al. Discovery and Resupply of Pharmacologically Active Plant-Derived Natural Products: A Review. *Biotechnol. Adv.* **2015**, *33*, 1582–1614. [CrossRef]
82. Yang, L.; Wen, K.-S.; Ruan, X.; Zhao, Y.-X.; Wei, F.; Wang, Q. Response of Plant Secondary Metabolites to Environmental Factors. *Molecules* **2018**, *23*, 762. [CrossRef]
83. Pang, Z.; Chen, J.; Wang, T.; Gao, C.; Li, Z.; Guo, L.; Xu, J.; Cheng, Y. Linking Plant Secondary Metabolites and Plant Microbiomes: A Review. *Front. Plant Sci.* **2021**, *12*, 621276. [CrossRef]
84. Koprivova, A.; Kopriva, S. Plant Secondary Metabolites Altering Root Microbiome Composition and Function. *Curr. Opin. Plant Biol.* **2022**, *67*, 102227. [CrossRef]
85. Twaij, B.M.; Hasan, M.N. Bioactive Secondary Metabolites from Plant Sources: Types, Synthesis, and Their Therapeutic Uses. *Int. J. Plant Biol.* **2022**, *13*, 4–14. [CrossRef]
86. El-Ramady, H.; Törős, G.; Badgar, K.; Llanaj, X.; Hajdú, P.; El-Mahrouk, M.E.; Abdalla, N.; Prokisch, J. A Comparative Photographic Review on Higher Plants and Macro-Fungi: A Soil Restoration for Sustainable Production of Food and Energy. *Sustainability* **2022**, *14*, 7104. [CrossRef]
87. Wawrosch, C.; Zotchev, S.B. Production of Bioactive Plant Secondary Metabolites through in Vitro Technologies—Status and Outlook. *Appl. Microbiol. Biotechnol.* **2021**, *105*, 6649–6668. [CrossRef] [PubMed]
88. Fazili, M.A.; Bashir, I.; Ahmad, M.; Yaqoob, U.; Geelani, S.N. In Vitro Strategies for the Enhancement of Secondary Metabolite Production in Plants: A Review. *Bull. Natl. Res. Cent.* **2022**, *46*, 35. [CrossRef]
89. Zhou, W.; Cheng, Y.; Zhu, P.; Nasser, M.I.; Zhang, X.; Zhao, M. Implication of Gut Microbiota in Cardiovascular Diseases. *Oxid. Med. Cell. Longev.* **2020**, *2020*, 5394096. [CrossRef] [PubMed]
90. AlAli, M.; Alqubaisy, M.; Aljaafari, M.N.; AlAli, A.O.; Baqais, L.; Molouki, A.; Abushelaibi, A.; Lai, K.-S.; Lim, S.-H.E. Nutraceuticals: Transformation of Conventional Foods into Health Promoters/Disease Preventers and Safety Considerations. *Molecules* **2021**, *26*, 2540. [CrossRef]
91. Murthy, H.N.; Paek, K.Y. Health Benefits of Underutilized Vegetables and Legumes. In *Bioactive Compounds in Underutilized Vegetables and Legumes*; Murthy, H.N., Paek, K.Y., Eds.; Reference Series in Phytochemistry; Springer International Publishing: Cham, Switzerland, 2021; pp. 1–36. ISBN 978-3-030-57414-7.
92. Rubatzky, V.E.; Yamaguchi, M. *World Vegetables: Principles, Production, and Nutritive Values*; Chapman & Hall: New York, UK, 1999; ISBN 978-0-8342-1687-7.
93. Bermejo, J.; Leon, J. *Neglected Crops: 1492 from a Different Perspective; FAO Plant Production and Protection Series, No 26*; Food and Agriculture Organization of the United Nations: Rome, Italy, 1995.
94. Oshodi, A.A.; Ipinmoroti, K.O.; Adeyeye, E.I.; Hall, G.M. Amino and Fatty Acids Composition of African Yam Bean (Sphenostylis Stenocarpa) Flour. *Food Chem.* **1995**, *53*, 1–6. [CrossRef]
95. Yamaguchi, M. *World Vegetables*; Van Nostrand Reinhold: New York, NY, USA, 1983.
96. Quattrocchi, U. *CRC World Dictionary of Plant Names: Common Names, Scientific Names, Eponyms, Synonyms and Etymology*; CRC Press: Boca Raton, FL, USA, 1999.
97. Sridhar, K.; Niveditha, V.R. Nutritional and Bioactive Potential of Coastal Sand Dune Wild Legume Canavalia Maritima (Aubl.) Thou.—An Overview. *Indian J. Nat. Prod. Resour.* **2014**, *5*, 107–120.
98. Dansi, A.; Vodouhè, R.; Azokpota, P.; Yedomonhan, H.; Assogba, P.; Adjatin, A.; Loko, Y.L.; Dossou-Aminon, I.; Akpagana, K. Diversity of the Neglected and Underutilized Crop Species of Importance in Benin. *Sci. World J.* **2012**, *2012*, e932947. [CrossRef]

99. Shivashankar, G.; Kulkarni, R. Lablab Purpureus. In *Plant Resources of Southeast Asia (PROSEA)*; Van Der Maesen, L.J.G., Somaatmadja, S., Eds.; No. 1, Pulses; 1 Health Benefits of Underutilized Vegetables and Legumes 31; PUDOC: Wageningen, The Netherlands, 1992; pp. 48–50.
100. Bhartiya, A.; Aditya, J.; Kant, L. Nutritional and Remedial Potential of an Underutilized Food Legume Horsegram (*Macrotyloma Uniflorum*): A Review. *J. Anim. Plant Sci.* **2015**, *53*, 1–6.
101. Lambein, F.; Travella, S.; Kuo, Y.-H.; Van Montagu, M.; Heijde, M. Grass Pea (*Lathyrus Sativus* L.): Orphan Crop, Nutraceutical or Just Plain Food? *Planta* **2019**, *250*, 821–838. [CrossRef] [PubMed]
102. Sathe, S.K.; Venkatachalam, M. Fractionation and Biochemical Characterization of Moth Bean (*Vigna Aconitifolia* L.) Proteins. *LWT-Food Sci. Technol.* **2007**, *40*, 600–610. [CrossRef]
103. Chhikara, N.; Devi, H.R.; Jaglan, S.; Sharma, P.; Gupta, P.; Panghal, A. Bioactive Compounds, Food Applications and Health Benefits of Parkia Speciosa (*Stinky Beans*): A Review. *Agric. Food Secur.* **2018**, *7*, 46. [CrossRef]
104. Morton, J.F. Pito (*Erythrina Berteroana*) and Chipilin (*Crotalaria Longirostrata*), (Fabaceae) Two Soporific Vegetables of Central America. *Econ. Bot.* **1994**, *48*, 130–138. [CrossRef]
105. Katoch, R. Nutritional Potential of Rice Bean (*Vigna Umbellata*): An Underutilized Legume. *J. Food Sci.* **2013**, *78*, C8-16. [CrossRef]
106. Schulke, E. A review on the nutritive value and toxic aspects of leucaena leucocephala. *Trop. Anim. Prod.* **1979**. Available online: https://www.google.com.hk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi1x9Po3-X4AhWFmVYBHRjbCKsQFnoECAYQAQ&url=https%3A%2F%2Fwww.cipav.org.co%2FTAP%2FTAP%2FTAP42%2F4_2_1.pdf&usg=AOvVaw01pzLRZy-ovwC_LdKb1A6u (accessed on 31 May 2022).
107. Assad, R.; Reshi, Z.A.; Jan, S.; Rashid, I. Biology of Amaranths. *Bot. Rev.* **2017**, *83*, 382–436. [CrossRef]
108. Read, B.E. Famine foods listed in the Chiu Huang Pen Ts'ao, giving their identity, nutritional values and notes on their preparation. In *Famine Foods Listed in the Chiu Huang Pen Is'ao Giving Their Identity Nutritional Values and Notes on Their Preparation*; The Henry Lester Institute of Medical Research: Shanghai, Beijing, 1977.
109. Wright, C. *Mediterranean Vegetables: A Cook's Compendium of All the Vegetables from The World's Healthiest Cuisine, with More than 200 Recipes*; Harvard Common Press: Boston, MA, USA, 2012; ISBN 978-1-55832-775-7.
110. Priyadarsini, K.I. The Chemistry of Curcumin: From Extraction to Therapeutic Agent. *Molecules* **2014**, *19*, 20091–20112. [CrossRef]
111. Robinson, R.W.; Decker-Walters, D.S. *Cucurbits*; CAB International: Oxon, UK; New York, NY, USA, 1997; ISBN 978-0-85199-133-7.
112. Mathew, B. *The Smaller Bulbs*; Batsford BT: London, UK, 1987.
113. Austin, D.F. Water Spinach (*Ipomoea Aquatica, Convolvulaceae*): A Food Gone Wild. *Ethnobot. Res. Appl.* **2007**, *5*, 123–146. [CrossRef]
114. Swarna, J.; Lokeswari, T.S.; Smita, M.; Ravindhran, R. Characterisation and Determination of in Vitro Antioxidant Potential of Betalains from *Talinum Triangulare* (Jacq.) Willd. *Food Chem.* **2013**, *141*, 4382–4390. [CrossRef]
115. Shah, F.H.; Kim, S.J. Therapeutic Role of Medicinal Plant Extracts and Bioactive Compounds in Osteoarthritis. *Adv. Tradit. Med.* **2022**. [CrossRef]
116. Phillipson, J.D. Phytochemistry and Medicinal Plants. *Phytochemistry* **2001**, *56*, 237–243. [CrossRef]
117. Min, G.-Y.; Park, J.-M.; Joo, I.-H.; Kim, D.-H. Inhibition Effect of Caragana Sinica Root Extracts on Osteoarthritis through MAPKs, NF-KB Signaling Pathway. *Int. J. Med. Sci.* **2021**, *18*, 861–872. [CrossRef] [PubMed]
118. Han, S.J.; Lim, M.J.; Lee, K.M.; Oh, E.; Shin, Y.S.; Kim, S.; Kim, J.S.; Yun, S.P.; Kang, L.-J. Safflower Seed Extract Attenuates the Development of Osteoarthritis by Blocking NF-KB Signaling. *Pharmaceuticals* **2021**, *14*, 258. [CrossRef]
119. Panter, K.E.; Welch, K.D.; Gardner, D.R.; Green, B.T. Poisonous Plants: Effects on Embryo and Fetal Development. *Birth Defects Res. Part C Embryo Today Rev.* **2013**, *99*, 223–234. [CrossRef]
120. Adnyana, I.K.; Sukandar, E.Y.; Setiawan, F.; Christanti, Y. Efficacy and Safety O-Desmethyl Quinine Compare to Quinine for Nocturnal Leg Cramp. *J. Med. Sci.* **2013**, *13*, 819–823. [CrossRef]
121. Kothari, P.; Tripathi, A.K.; Girme, A.; Rai, D.; Singh, R.; Sinha, S.; Choudhary, D.; Nagar, G.K.; Maurya, R.; Hingorani, L.; et al. Caviunin Glycoside (CAFG) from Dalbergia Sissoo Attenuates Osteoarthritis by Modulating Chondrogenic and Matrix Regulating Proteins. *J. Ethnopharmacol.* **2022**, *282*, 114315. [CrossRef]
122. Russo, P.; Frustaci, A.; Del Bufalo, A.; Fini, M.; Cesario, A. Multitarget Drugs of Plants Origin Acting on Alzheimer's Disease. *Curr. Med. Chem.* **2013**, *20*, 1686–1693. [CrossRef]
123. Chen, D.-H.; Zheng, G.; Zhong, X.-Y.; Lin, Z.-H.; Yang, S.-W.; Liu, H.-X.; Shang, P. Oroxylin A Attenuates Osteoarthritis Progression by Dual Inhibition of Cell Inflammation and Hypertrophy. *Food Funct.* **2021**, *12*, 328–339. [CrossRef]
124. Rozov-Ung, I.; Mreyoud, A.; Moore, J.; Wilding, G.E.; Khawam, E.; Lackner, J.M.; Semler, J.R.; Sitrin, M.D. Detection of Drug Effects on Gastric Emptying and Contractility Using a Wireless Motility Capsule. *BMC Gastroenterol.* **2014**, *14*, 2. [CrossRef]
125. Simera, M.; Poliacek, I.; Jakus, J. Central Antitussive Effect of Codeine in the Anesthetized Rabbit. *Eur. J. Med. Res.* **2010**, *15* (Suppl. 2), 184–188. [CrossRef] [PubMed]
126. Jeong, I.H.; Kim, Y.S.; Cho, K.Y.; Kim, K.J. Unexpected Effect of Fluorine in Diels-Alder Reaction of 2-Fluoroacrolein with Thebaine. *Bull. Korean Chem. Soc.* **1990**, *11*, 178–179. [CrossRef]
127. Xu, Z.; Shen, Z.; Wu, B.; Gong, S.; Chen, B. Small Molecule Natural Compound Targets the NF-κB Signaling and Ameliorates the Development of Osteoarthritis. *J. Cell. Physiol.* **2021**, *236*, 7298–7307. [CrossRef]
128. Yan, J.; Ni, B.; Sheng, G.; Zhang, Y.; Xiao, Y.; Ma, Y.; Li, H.; Wu, H.; Tu, C. Rhoifolin Ameliorates Osteoarthritis via Regulating Autophagy. *Front. Pharmacol.* **2021**, *12*, 661072. [CrossRef] [PubMed]

129. Ma, N.L.; Lam, S.D.; Che Lah, W.A.; Ahmad, A.; Rinklebe, J.; Sonne, C.; Peng, W. Integration of Environmental Metabolomics and Physiological Approach for Evaluation of Saline Pollution to Rice Plant. *Environ. Pollut.* **2021**, *286*, 117214. [CrossRef] [PubMed]
130. Veldkamp, J.F. A Revision of Sarcotheca Bl. and Dapania Korth. (Oxalidaceae). *Blumea Biodivers. Evol. Biogeogr. Plants* **1967**, *15*, 519–543.
131. *U.S. Patent 20130123106*; Gandhi, P.T. Novel Nicotine Derivatives 2013. USPTO (United States Patent and Trademark Office): Alexandria, VA, USA, 16 May 2013.
132. Lu, M.-K.; Shih, Y.-W.; Chang Chien, T.-T.; Fang, L.-H.; Huang, H.-C.; Chen, P.-S. α-Solanine Inhibits Human Melanoma Cell Migration and Invasion by Reducing Matrix Metalloproteinase-2/9 Activities. *Biol. Pharm. Bull.* **2010**, *33*, 1685–1691. [CrossRef]
133. Morrow, W.J.W.; Yang, Y.-W.; Sheikh, N.A. Immunobiology of the Tomatine Adjuvant. *Vaccine* **2004**, *22*, 2380–2384. [CrossRef]
134. Onwurah, N.; Eke, I.; Anaga, A. Antiulcer Properties of Aqueous Extract of Talinum Triangulare Leaves in Experimentally Induced Gastric Ulceration in Mice. *Asian J. Pharm. Biol. Res.* **2013**, *3*, 4–7.
135. Huang, S.; Wang, P.; Yamaji, N.; Ma, J.F. Plant Nutrition for Human Nutrition: Hints from Rice Research and Future Perspectives. *Mol. Plant* **2020**, *13*, 825–835. [CrossRef]
136. Mena, P.; Angelino, D. Plant Food, Nutrition, and Human Health. *Nutrients* **2020**, *12*, 2157. [CrossRef]
137. Brevik, E.C.; Slaughter, L.; Singh, B.R.; Steffan, J.J.; Collier, D.; Barnhart, P.; Pereira, P. Soil and Human Health: Current Status and Future Needs. *Air Soil Water Res.* **2020**, *13*, 117862212093444. [CrossRef]
138. Stein, A.J. Global Impacts of Human Mineral Malnutrition. *Plant Soil* **2010**, *335*, 133–154. [CrossRef]
139. Szerement, J.; Szatanik-Kloc, A.; Mokrzycki, J.; Mierzwa-Hersztek, M. Agronomic Biofortification with Se, Zn, and Fe: An Effective Strategy to Enhance Crop Nutritional Quality and Stress Defense—A Review. *J. Soil Sci. Plant Nutr.* **2022**, *22*, 1129–1159. [CrossRef]
140. Kumar, S.; Dikshit, H.K.; Mishra, G.P.; Singh, A. *Biofortification of Staple Crops*; Springer Nature Singapore Pte Ltd.: Singapore, 2022.
141. Kumar, S.; Dikshit, H.K.; Mishra, G.P.; Singh, A.; Aski, M.; Virk, P.S. Biofortification of Staple Crops: Present Status and Future Strategies. In *Biofortification of Staple Crops*; Kumar, S., Dikshit, H.K., Mishra, G.P., Singh, A., Eds.; Springer: Singapore, 2022; pp. 1–30. ISBN 9789811632808.
142. Schiavon, M.; Nardi, S.; Dalla Vecchia, F.; Ertani, A. Selenium Biofortification in the 21st Century: Status and Challenges for Healthy Human Nutrition. *Plant Soil* **2020**, *453*, 245–270. [CrossRef]
143. Sharma, D.; Jamra, G.; Singh, U.M.; Sood, S.; Kumar, A. Calcium Biofortification: Three Pronged Molecular Approaches for Dissecting Complex Trait of Calcium Nutrition in Finger Millet (Eleusine Coracana) for Devising Strategies of Enrichment of Food Crops. *Front. Plant Sci.* **2017**, *7*, 2028. [CrossRef]
144. Mishra, G.P.; Dikshit, H.K.; Priti; Kukreja, B.; Aski, M.; Yadava, D.K.; Sarker, A.; Kumar, S. Historical Overview of Biofortification in Crop Plants and Its Implications. In *Biofortification of Staple Crops*; Kumar, S., Dikshit, H.K., Mishra, G.P., Singh, A., Eds.; Springer: Singapore, 2022; pp. 31–61. ISBN 9789811632792.
145. Dobermann, A.; Bruulsema, T.; Cakmak, I.; Gerard, B.; Majumdar, K.; McLaughlin, M.; Reidsma, P.; Vanlauwe, B.; Wollenberg, L.; Zhang, F.; et al. Responsible Plant Nutrition: A New Paradigm to Support Food System Transformation. *Glob. Food Secur.* **2022**, *33*, 100636. [CrossRef]
146. Feliciano, D.; Recha, J.; Ambaw, G.; MacSween, K.; Solomon, D.; Wollenberg, E. Assessment of Agricultural Emissions, Climate Change Mitigation and Adaptation Practices in Ethiopia. *Clim. Policy* **2022**, *22*, 427–444. [CrossRef]
147. Abbass, K.; Qasim, M.Z.; Song, H.; Murshed, M.; Mahmood, H.; Younis, I. A Review of the Global Climate Change Impacts, Adaptation, and Sustainable Mitigation Measures. *Environ. Sci. Pollut. Res.* **2022**, *29*, 42539–42559. [CrossRef]
148. Heckathorn, S.; North, G.; Wang, D.; Zhu, C. Editorial: Climate Change and Plant Nutrient Relations. *Front. Plant Sci.* **2020**, *11*, 869. [CrossRef]
149. Soares, J.C.; Santos, C.S.; Carvalho, S.M.P.; Pintado, M.M.; Vasconcelos, M.W. Preserving the Nutritional Quality of Crop Plants under a Changing Climate: Importance and Strategies. *Plant Soil* **2019**, *443*, 1–26. [CrossRef]
150. Cracknell, P.; Varotsos, C. Understanding Global Climate Change: Modelling the Climatic System and Human Impacts. CRC Press Is an Imprint of Taylor & Francis Group, LLC, Second Edition Arthur. Available online: https://www.routledge.com/Understanding-Global-Climate-Change-Modelling-the-Climatic-System-and-Human/Cracknell-Varotsos/p/book/9781032001616 (accessed on 31 May 2022).
151. Nielsen, R.L.; James, J.J.; Drenovsky, R.E. Functional Traits Explain Variation in Chaparral Shrub Sensitivity to Altered Water and Nutrient Availability. *Front. Plant Sci.* **2019**, *10*, 505. [CrossRef] [PubMed]
152. Sharma, R.; Singh, H. Alteration in Biochemical Constituents and Nutrients Partitioning of *Asparagus Racemosus* in Response to Elevated Atmospheric CO2 Concentration. *Environ. Sci. Pollut. Res.* **2022**, *29*, 6812–6821. [CrossRef] [PubMed]
153. Kovak, E.; Blaustein-Rejto, D.; Qaim, M. Genetically Modified Crops Support Climate Change Mitigation. *Trends Plant Sci.* **2022**, *27*, 627–629. [CrossRef]
154. Kumar, A.; Bhattacharya, T.; Mukherjee, S.; Sarkar, B. A Perspective on Biochar for Repairing Damages in the Soil–Plant System Caused by Climate Change-Driven Extreme Weather Events. *Biochar* **2022**, *4*, 22. [CrossRef]
155. Wright, C.Y.; Kapwata, T.; du Preez, D.J.; Wernecke, B.; Garland, R.M.; Nkosi, V.; Landman, W.A.; Dyson, L.; Norval, M. Major Climate Change-Induced Risks to Human Health in South Africa. *Environ. Res.* **2021**, *196*, 110973. [CrossRef]
156. Zhao, Q.; Yu, P.; Mahendran, R.; Huang, W.; Gao, Y.; Yang, Z.; Ye, T.; Wen, B.; Wu, Y.; Li, S.; et al. Global Climate Change and Human Health: Pathways and Possible Solutions. *Eco-Environ. Health* **2022**, *1*, 53–62. [CrossRef]

157. Ayi, Q.; Zeng, B.; Yang, K.; Lin, F.; Zhang, X.; van Bodegom, P.M.; Cornelissen, J.H.C. Similar Growth Performance but Contrasting Biomass Allocation of Root-Flooded Terrestrial Plant Alternanthera Philoxeroides (Mart.) Griseb. in Response to Nutrient Versus Dissolved Oxygen Stress. *Front. Plant Sci.* **2019**, *10*, 111. [CrossRef]
158. Xu, H.; Xie, H.; Wu, S.; Wang, Z.; He, K. Effects of Elevated CO_2 and Increased N Fertilization on Plant Secondary Metabolites and Chewing Insect Fitness. *Front. Plant Sci.* **2019**, *10*, 739. [CrossRef]
159. Li, Y.; Yu, Z.; Jin, J.; Zhang, Q.; Wang, G.; Liu, C.; Wu, J.; Wang, C.; Liu, X. Impact of Elevated CO_2 on Seed Quality of Soybean at the Fresh Edible and Mature Stages. *Front. Plant Sci.* **2018**, *9*, 1413. [CrossRef]
160. Dong, J.; Gruda, N.; Lam, S.K.; Li, X.; Duan, Z. Effects of Elevated CO_2 on Nutritional Quality of Vegetables: A Review. *Front. Plant Sci.* **2018**, *9*, 924. [CrossRef] [PubMed]
161. Bedeke, S.B. Climate Change Vulnerability and Adaptation of Crop Producers in Sub-Saharan Africa: A Review on Concepts, Approaches and Methods. *Environ. Dev. Sustain.* **2022**, 1–35. [CrossRef]
162. Vanisree, C.R.; Singh, P.; Jadhav, E.B.; Nair, M.S.; Sankhla, M.S.; Parihar, K.; Awasthi, K.K. Effect of Climate Change and Soil Dynamics on Soil Microbes and Fertility of Soil. In *Microbiome under Changing Climate*; Elsevier: Amsterdam, The Netherlands, 2022; pp. 437–468. ISBN 978-0-323-90571-8.
163. Collado-González, J.; Piñero, M.C.; Otalora, G.; Lopez-Marín, J.; del Amor, F.M. Unraveling the Nutritional and Bioactive Constituents in Baby-Leaf Lettuce for Challenging Climate Conditions. *Food Chem.* **2022**, *384*, 132506. [CrossRef] [PubMed]
164. Rodrigues Arruda, T.; Campos Bernardes, P.; Robledo Fialho e Moraes, A.; de Fátima Ferreira Soares, N. Natural Bioactives in Perspective: The Future of Active Packaging Based on Essential Oils and Plant Extracts Themselves and Those Complexed by Cyclodextrins. *Food Res. Int.* **2022**, *156*, 111160. [CrossRef] [PubMed]
165. Jamloki, A.; Bhattacharyya, M.; Nautiyal, M.C.; Patni, B. Elucidating the Relevance of High Temperature and Elevated CO_2 in Plant Secondary Metabolites (PSMs) Production. *Heliyon* **2021**, *7*, e07709. [CrossRef]
166. Lupitu, A.; Moisa, C.; Gavrilaş, S.; Dochia, M.; Chambre, D.; Ciutină, V.; Copolovici, D.M.; Copolovici, L. The Influence of Elevated CO_2 on Volatile Emissions, Photosynthetic Characteristics, and Pigment Content in Brassicaceae Plants Species and Varieties. *Plants* **2022**, *11*, 973. [CrossRef]
167. Yamuangmorn, S.; Jumrus, S.; Jamjod, S.; Sringarm, K.; Arjin, C.; Prom-u-thai, C. Responses of Purple Rice Variety to Light Intensities and Soil Zinc Application on Plant Growth, Yield and Bioactive Compounds Synthesis. *J. Cereal Sci.* **2022**, *106*, 103495. [CrossRef]
168. Ramani, S.; Jayabaskaran, C. Enhanced Catharanthine and Vindoline Production in Suspension Cultures of Catharanthus Roseus by Ultraviolet-B Light. *J. Mol. Signal.* **2008**, *3*, 9. [CrossRef]
169. Regvar, M.; Bukovnik, U.; Likar, M.; Kreft, I. UV-B Radiation Affects Flavonoids and Fungal Colonisation in Fagopyrum Esculentum and F. Tataricum. *Open Life Sci.* **2012**, *7*, 275–283. [CrossRef]
170. Cuadra, P.; Harborne, J.B.; Waterman, P.G. Increases in Surface Flavonols and Photosynthetic Pigments in *Gnaphalium Luteo-Album* in Response to UV-B Radiation. *Phytochemistry* **1997**, *45*, 1377–1383. [CrossRef]
171. Zu, Y.-G.; Tang, Z.-H.; Yu, J.-H.; Liu, S.-G.; Wang, W.; Guo, X.-R. Different Responses of Camptothecin and 10-Hydroxycamptothecin to Heat Shock in Camptotheca Acuminata Seedlings. *Acta Bot. Sin.* **2003**, *45*, 809–814.
172. Commisso, M.; Toffali, K.; Strazzer, P.; Stocchero, M.; Ceoldo, S.; Baldan, B.; Levi, M.; Guzzo, F. Impact of Phenylpropanoid Compounds on Heat Stress Tolerance in Carrot Cell Cultures. *Front. Plant Sci.* **2016**, *7*, 1439. [CrossRef]
173. Hanson, D.T.; Sharkey, T.D. Effect of Growth Conditions on Isoprene Emission and Other Thermotolerance-Enhancing Compounds. *Plant Cell Environ.* **2001**, *24*, 929–936. [CrossRef]
174. Rosenfeld, H.J.; Aaby, K.; Lea, P. Influence of Temperature and Plant Density on Sensory Quality and Volatile Terpenoids of Carrot (Daucus Carota L.) Root. *J. Sci. Food Agric.* **2002**, *82*, 1384–1390. [CrossRef]
175. Lee, J.-Y.; Son, K.-H.; Lee, J.-H.; Oh, M.-M. Growth Characteristics and Bioactive Compounds of Dropwort Subjected to High CO_2 Concentrations and Water Deficit. *Hortic. Environ. Biotechnol.* **2022**, *63*, 181–194. [CrossRef]
176. Ahmed, M.M.; Hagagy, N.; AbdElgawad, H. Establishment of Actinobacteria–Satureja Hortensis Interactions under Future Climate CO_2-Enhanced Crop Productivity in Drought Environments of Saudi Arabia. *Environ. Sci. Pollut. Res.* **2021**, *28*, 62853–62867. [CrossRef]
177. AbdElgawad, H.; Okla, M.K.; Al-amri, S.S.; AL-Hashimi, A.; AL-Qahtani, W.H.; Al-Qahtani, S.M.; Abbas, Z.K.; Al-Harbi, N.A.; Abd Algafar, A.; Almuhayawi, M.S.; et al. Effect of Elevated CO_2 on Biomolecules' Accumulation in Caraway (*Carum Carvi* L.) Plants at Different Developmental Stages. *Plants* **2021**, *10*, 2434. [CrossRef]
178. Selim, S.; Abuelsoud, W.; Al-Sanea, M.M.; AbdElgawad, H. Elevated CO_2 Differently Suppresses the Arsenic Oxide Nanoparticles-Induced Stress in C3 (Hordeum Vulgare) and C4 (Zea Maize) Plants via Altered Homeostasis in Metabolites Specifically Proline and Anthocyanin Metabolism. *Plant Physiol. Biochem.* **2021**, *166*, 235–245. [CrossRef]
179. Almuhayawi, M.S.; Al Jaouni, S.K.; Almuhayawi, S.M.; Selim, S.; Abdel-Mawgoud, M. Elevated CO_2 Improves the Nutritive Value, Antibacterial, Anti-Inflammatory, Antioxidant and Hypocholestecolemic Activities of Lemongrass Sprouts. *Food Chem.* **2021**, *357*, 129730. [CrossRef]
180. Qiang, Q.; Gao, Y.; Yu, B.; Wang, M.; Ni, W.; Li, S.; Zhang, T.; Li, W.; Lin, L. Elevated CO_2 Enhances Growth and Differentially Affects Saponin Content in Paris Polyphylla Var. Yunnanensis. *Ind. Crops Prod.* **2020**, *147*, 112124. [CrossRef]
181. Lee, H.R.; Kim, H.M.; Jeong, H.W.; Oh, M.M.; Hwang, S.J. Growth and Bioactive Compound Content of Glehnia Littoralis Fr. Schmidt Ex Miquel Grown under Different CO_2 Concentrations and Light Intensities. *Plants* **2020**, *9*, 1581. [CrossRef] [PubMed]

182. Li, L.; Wang, M.; Pokharel, S.S.; Li, C.; Parajulee, M.N.; Chen, F.; Fang, W. Effects of Elevated CO_2 on Foliar Soluble Nutrients and Functional Components of Tea, and Population Dynamics of *Tea Aphid, Toxoptera Aurantii*. *Plant Physiol. Biochem.* **2019**, *145*, 84–94. [CrossRef] [PubMed]
183. Chang, J.; Mantri, N.; Sun, B.; Jiang, L.; Chen, P.; Jiang, B.; Jiang, Z.; Zhang, J.; Shen, J.; Lu, H.; et al. Effects of Elevated CO_2 and Temperature on *Gynostemma Pentaphyllum* Physiology and Bioactive Compounds. *J. Plant Physiol.* **2016**, *196–197*, 41–52. [CrossRef] [PubMed]
184. Campanale, C.; Galafassi, S.; Savino, I.; Massarelli, C.; Ancona, V.; Volta, P.; Uricchio, V.F. Microplastics Pollution in the Terrestrial Environments: Poorly Known Diffuse Sources and Implications for Plants. *Sci. Total Environ.* **2022**, *805*, 150431. [CrossRef] [PubMed]
185. Nawab, J.; Ghani, J.; Khan, S.; Xiaoping, W. Minimizing the Risk to Human Health Due to the Ingestion of Arsenic and Toxic Metals in Vegetables by the Application of Biochar, Farmyard Manure and Peat Moss. *J. Environ. Manag.* **2018**, *214*, 172–183. [CrossRef]
186. Singh, S.; Parihar, P.; Singh, R.; Singh, V.P.; Prasad, S.M. Heavy Metal Tolerance in Plants: Role of Transcriptomics, Proteomics, Metabolomics, and Ionomics. *Front. Plant Sci.* **2016**, *6*, 1143. [CrossRef]
187. Montano, L.; Maugeri, A.; Volpe, M.G.; Micali, S.; Mirone, V.; Mantovani, A.; Navarra, M.; Piscopo, M. Mediterranean Diet as a Shield against Male Infertility and Cancer Risk Induced by Environmental Pollutants: A Focus on Flavonoids. *Int. J. Mol. Sci.* **2022**, *23*, 1568. [CrossRef]
188. Banerjee, S.; Banerjee, A.; Palit, D. Morphological and Biochemical Study of Plant Species- a Quick Tool for Assessing the Impact of Air Pollution. *J. Clean. Prod.* **2022**, *339*, 130647. [CrossRef]
189. Khan, M.A.; Ding, X.; Khan, S.; Brusseau, M.L.; Khan, A.; Nawab, J. The Influence of Various Organic Amendments on the Bioavailability and Plant Uptake of Cadmium Present in Mine-Degraded Soil. *Sci. Total Environ.* **2018**, *636*, 810–817. [CrossRef]
190. Elbagory, M.; Farrag, D.K.; Hashim, A.M.; Omara, A.E.-D. The Combined Effect of Pseudomonas Stutzeri and Biochar on the Growth Dynamics and Tolerance of Lettuce Plants (Lactuca Sativa) to Cadmium Stress. *Horticulturae* **2021**, *7*, 430. [CrossRef]
191. Mukherjee, S.; Chatterjee, N.; Sircar, A.; Maikap, S.; Singh, A.; Acharyya, S.; Paul, S. A Comparative Analysis of Heavy Metal Effects on Medicinal Plants. *Appl. Biochem. Biotechnol.* **2022**, 1–36. [CrossRef] [PubMed]
192. Asgari Lajayer, B.; Ghorbanpour, M.; Nikabadi, S. Heavy Metals in Contaminated Environment: Destiny of Secondary Metabolite Biosynthesis, Oxidative Status and Phytoextraction in Medicinal Plants. *Ecotoxicol. Environ. Saf.* **2017**, *145*, 377–390. [CrossRef] [PubMed]
193. Haruna, A.; Yahaya, S.M. Recent Advances in the Chemistry of Bioactive Compounds from Plants and Soil Microbes: A Review. *Chem. Afr.* **2021**, *4*, 231–248. [CrossRef]
194. Zhang, C.; Jia, X.; Zhao, Y.; Wang, L.; Cao, K.; Zhang, N.; Gao, Y.; Wang, Z. The Combined Effects of Elevated Atmospheric CO_2 and Cadmium Exposure on Flavonoids in the Leaves of Robinia Pseudoacacia L. Seedlings. *Ecotoxicol. Environ. Saf.* **2021**, *210*, 111878. [CrossRef] [PubMed]
195. Lacavé, G.; Soto-Maldonado, C.; Walter, A.; Zúñiga-Hansen, M.; Pérez-Torres, E. Effect of Drought Stress on Bioactives and Starch in Chilean Potato Landraces. *Potato Res.* **2022**, 1–20. [CrossRef]
196. Esmaili, S.; Tavallali, V.; Amiri, B.; Bazrafshan, F.; Sharafzadeh, S. Foliar Application of Nano-Silicon Complexes on Growth, Oxidative Damage and Bioactive Compounds of Feverfew Under Drought Stress. *Silicon* **2022**, 1–12. [CrossRef]
197. Hernández, I.; Alegre, L.; Munné-Bosch, S. Drought-Induced Changes in Flavonoids and Other Low Molecular Weight Antioxidants in Cistus Clusii Grown under Mediterranean Field Conditions. *Tree Physiol.* **2004**, *24*, 1303–1311. [CrossRef]
198. Kirakosyan, A.; Kaufman, P.; Warber, S.; Zick, S.; Aaronson, K.; Bolling, S.; Chul Chang, S. Applied Environmental Stresses to Enhance the Levels of Polyphenolics in Leaves of Hawthorn Plants. *Physiol. Plant.* **2004**, *121*, 182–186. [CrossRef]
199. Cho, Y.; Njiti, V.N.; Chen, X.; Lightfoot, D.A.; Wood, A.J. Trigonelline Concentration in Field-Grown Soybean in Response to Irrigation. *Biol. Plant.* **2003**, *46*, 405–410. [CrossRef]
200. Nacif de Abreu, I.; Mazzafera, P. Effect of Water and Temperature Stress on the Content of Active Constituents of Hypericum Brasiliense Choisy. *Plant Physiol. Biochem.* **2005**, *43*, 241–248. [CrossRef]
201. Karmous, I.; Gammoudi, N.; Chaoui, A. Assessing the Potential Role of Zinc Oxide Nanoparticles for Mitigating Cadmium Toxicity in Capsicum Annuum L. Under In Vitro Conditions. *J. Plant Growth Regul.* **2022**, 1–16. [CrossRef]
202. Hayat, K.; Zhou, Y.; Menhas, S.; Hayat, S.; Aftab, T.; Bundschuh, J.; Zhou, P. Salicylic Acid Confers Salt Tolerance in Giant Juncao Through Modulation of Redox Homeostasis, Ionic Flux, and Bioactive Compounds: An Ionomics and Metabolomic Perspective of Induced Tolerance Responses. *J. Plant Growth Regul.* **2022**, *41*, 1999–2019. [CrossRef]
203. Khare, S.; Singh, N.B.; Niharika; Singh, A.; Amist, N.; Azim, Z.; Bano, C.; Yadav, V.; Yadav, R.K. Salinity-Induced Attenuation in Secondary Metabolites Profile and Herbicidal Potential of *Brassica Nigra* L. on *Anagallis Arvensis* L. *J. Plant Growth Regul.* **2022**, 1–16. [CrossRef]
204. Mogazy, A.M.; Hanafy, R.S. Foliar Spray of Biosynthesized Zinc Oxide Nanoparticles Alleviate Salinity Stress Effect on Vicia Faba Plants. *J. Soil Sci. Plant Nutr.* **2022**, *22*, 2647–2662. [CrossRef]
205. Nouman, W.; Aziz, U. Seed Priming Improves Salinity Tolerance in Calotropis Procera (Aiton) by Increasing Photosynthetic Pigments, Antioxidant Activities, and Phenolic Acids. *Biologia* **2022**, *77*, 609–626. [CrossRef]
206. Farooq, T.; Nisa, Z.U.; Hameed, A.; Ahmed, T.; Hameed, A. Priming with Copper-Chitosan Nanoparticles Elicit Tolerance against PEG-Induced Hyperosmotic Stress and Salinity in Wheat. *BMC Chem.* **2022**, *16*, 23. [CrossRef]

207. Dutta, A.; Sen, J.; Deswal, R. Downregulation of Terpenoid Indole Alkaloid Biosynthetic Pathway by Low Temperature and Cloning of a AP2 Type C-Repeat Binding Factor (CBF) from *Catharanthus Roseus* (L). G. Don. *Plant Cell Rep.* **2007**, *26*, 1869–1878. [CrossRef]
208. Janas, K.M.; Cvikrová, M.; Pałagiewicz, A.; Szafranska, K.; Posmyk, M.M. Constitutive Elevated Accumulation of Phenylpropanoids in Soybean Roots at Low Temperature. *Plant Sci.* **2002**, *163*, 369–373. [CrossRef]
209. Copolovici, L.; Kännaste, A.; Pazouki, L.; Niinemets, Ü. Emissions of Green Leaf Volatiles and Terpenoids from Solanum Lycopersicum Are Quantitatively Related to the Severity of Cold and Heat Shock Treatments. *J. Plant Physiol.* **2012**, *169*, 664–672. [CrossRef]
210. Mir, B.A.; Mir, S.A.; Khazir, J.; Tonfack, L.B.; Cowan, D.A.; Vyas, D.; Koul, S. Cold Stress Affects Antioxidative Response and Accumulation of Medicinally Important Withanolides in *Withania Somnifera* (L.) Dunal. *Ind. Crops Prod.* **2015**, *74*, 1008–1016. [CrossRef]
211. Christie, P.J.; Alfenito, M.R.; Walbot, V. Impact of Low-Temperature Stress on General Phenylpropanoid and Anthocyanin Pathways: Enhancement of Transcript Abundance and Anthocyanin Pigmentation in Maize Seedlings. *Planta* **1994**, *194*, 541–549. [CrossRef]
212. Sharma, P.; Khanna, V.; Kumari, S. Abiotic Stress Mitigation Through Plant-Growth-Promoting Rhizobacteria. In *Plant-Microbe Interaction: An Approach to Sustainable Agriculture*; Choudhary, D.K., Varma, A., Tuteja, N., Eds.; Springe: Singapore, 2016; pp. 327–342. ISBN 978-981-10-2853-3.
213. Zeng, W.; Mostafa, S.; Lu, Z.; Jin, B. Melatonin-Mediated Abiotic Stress Tolerance in Plants. *Front. Plant Sci.* **2022**, *13*, 847175. [CrossRef] [PubMed]
214. Negacz, K.; Malek, Ž.; de Vos, A.; Vellinga, P. Saline Soils Worldwide: Identifying the Most Promising Areas for Saline Agriculture. *J. Arid Environ.* **2022**, *203*, 104775. [CrossRef]
215. Gupta, B.; Huang, B. Mechanism of Salinity Tolerance in Plants: Physiological, Biochemical, and Molecular Characterization. *Int. J. Genom.* **2014**, *2014*, 1–18. [CrossRef] [PubMed]
216. Neupane, D.; Adhikari, P.; Bhattarai, D.; Rana, B.; Ahmed, Z.; Sharma, U.; Adhikari, D. Does Climate Change Affect the Yield of the Top Three Cereals and Food Security in the World? *Earth* **2022**, *3*, 45–71. [CrossRef]
217. Paul, D.; Lade, H. Plant-Growth-Promoting Rhizobacteria to Improve Crop Growth in Saline Soils: A Review. *Agron. Sustain. Dev.* **2014**, *34*, 737–752. [CrossRef]
218. Molnár, Z.; Virág, E.; Ördög, V. Natural Substances in Tissue Culture Media of Higher Plants. *Acta Biol. Szeged.* **2011**, *55*, 123–127.
219. Köninger, J.; Lugato, E.; Panagos, P.; Kochupillai, M.; Orgiazzi, A.; Briones, M.J.I. Manure Management and Soil Biodiversity: Towards More Sustainable Food Systems in the EU. *Agric. Syst.* **2021**, *194*, 103251. [CrossRef]
220. Yeshi, K.; Crayn, D.; Ritmejerytė, E.; Wangchuk, P. Plant Secondary Metabolites Produced in Response to Abiotic Stresses Has Potential Application in Pharmaceutical Product Development. *Molecules* **2022**, *27*, 313. [CrossRef]
221. Jogawat, A.; Yadav, B.; Chhaya; Lakra, N.; Singh, A.K.; Narayan, O.P. Crosstalk between Phytohormones and Secondary Metabolites in the Drought Stress Tolerance of Crop Plants: A Review. *Physiol. Plant.* **2021**, *172*, 1106–1132. [CrossRef]
222. Li, Y.; Kong, D.; Fu, Y.; Sussman, M.R.; Wu, H. The Effect of Developmental and Environmental Factors on Secondary Metabolites in Medicinal Plants. *Plant Physiol. Biochem.* **2020**, *148*, 80–89. [CrossRef]
223. Yadav, B.; Jogawat, A.; Rahman, M.S.; Narayan, O.P. Secondary Metabolites in the Drought Stress Tolerance of Crop Plants: A Review. *Gene Rep.* **2021**, *23*, 101040. [CrossRef]
224. Yin, X.; Yan, X.; Qian, C.; Zhou, S.; Fang, T.; Fan, X.; Gao, Y.; Chang, Y.; Yang, J.; Ma, X.-F. Comparative Transcriptome Analysis to Identify Genes Involved in Terpenoid Biosynthesis in Agriophyllum Squarrosum, a Folk Medicinal Herb Native to Asian Temperature Deserts. *Plant Biotechnol. Rep.* **2021**, *15*, 369–387. [CrossRef]
225. Cheynier, V.; Comte, G.; Davies, K.M.; Lattanzio, V.; Martens, S. Plant Phenolics: Recent Advances on Their Biosynthesis, Genetics, and Ecophysiology. *Plant Physiol. Biochem.* **2013**, *72*, 1–20. [CrossRef]
226. Wangchuk, P. *Plant Alkaloids: Classification, Isolation and Drug Development*; Swamy, M., Patra, J., Rudramurthy, G., Eds.; Taylor & Francis Ltd.: Boca Raton, FL, USA, 2019; pp. 131–137. ISBN 978-0-367-11172-4.
227. Heinrich, M.; Mah, J.; Amirkia, V. Alkaloids Used as Medicines: Structural Phytochemistry Meets Biodiversity—An Update and Forward Look. *Molecules* **2021**, *26*, 1836. [CrossRef] [PubMed]
228. Espinosa-Leal, C.A.; Puente-Garza, C.A.; García-Lara, S. In Vitro Plant Tissue Culture: Means for Production of Biological Active Compounds. *Planta* **2018**, *248*, 1–18. [CrossRef]
229. Arora, K.; Rai, M.K.; Sharma, A.K. Tissue Culture Mediated Biotechnological Interventions in Medicinal Trees: Recent Progress. *Plant Cell Tissue Organ Cult. PCTOC* **2022**, 1–22. [CrossRef]
230. Mishra, V.K.; Bajpai, R.; Chaturvedi, R. Androgenic Haploid Plant Development via Embryogenesis with Simultaneous Determination of Bioactive Metabolites in Cambod Tea (Camellia Assamica Ssp. Lasiocalyx). *Plant Cell Tissue Organ Cult. PCTOC* **2022**, *148*, 515–531. [CrossRef]
231. Keshavan, B.; Santosh Srinivas, N.; Muthu Tamizh, M.; Vairamani, M.; Pachaiappan, R. In Vitro Elicitation of Camptothecin by Challenging with Biotic Elicitors in Nothapodytes Nimmoniana (J.Graham) Mabb. *S. Afr. J. Bot.* **2022**, *144*, 325–331. [CrossRef]
232. Escrich, A.; Almagro, L.; Moyano, E.; Cusido, R.M.; Bonfill, M.; Hosseini, B.; Palazon, J. Improved Biotechnological Production of Paclitaxel in Taxus Media Cell Cultures by the Combined Action of Coronatine and Calix[8]Arenes. *Plant Physiol. Biochem.* **2021**, *163*, 68–75. [CrossRef]

233. Rind, N.A.; Rind, K.H.; Dahot, M.U.; Faiza, H.; Aksoy, Ö.; Rind, K.H.; Shar, A.H.; Ullah, H.; Jatoi, A.H. Production of Limonoids Through Callus and Cell Suspension Cultures of Chinaberry (*Melia Azedarach* L.). *Bangladesh J. Bot.* **2021**, *50*, 301–309. [CrossRef]
234. Farjaminezhad, R.; Garoosi, G. Improvement and Prediction of Secondary Metabolites Production under Yeast Extract Elicitation of Azadirachta Indica Cell Suspension Culture Using Response Surface Methodology. *AMB Express* **2021**, *11*, 43. [CrossRef]
235. Farjaminezhad, R.; Garoosi, G. Prediction of the Effect of Chitosan on Cell Suspension Culture of Azadirachta Indica by Response Surface Methodology. *Plant Cell Tissue Organ Cult. PCTOC* **2021**, *146*, 323–337. [CrossRef]
236. Modarres, M.; Esmaeilzadeh Bahabadi, S.; Taghavizadeh Yazdi, M.E. Enhanced Production of Phenolic Acids in Cell Suspension Culture of Salvia Leriifolia Benth. Using Growth Regulators and Sucrose. *Cytotechnology* **2018**, *70*, 741–750. [CrossRef] [PubMed]
237. Ashokhan, S.; Othman, R.; Abd Rahim, M.H.; Karsani, S.A.; Yaacob, J.S. Effect of Plant Growth Regulators on Coloured Callus Formation and Accumulation of Azadirachtin, an Essential Biopesticide in *Azadirachta Indica*. *Plants* **2020**, *9*, 352. [CrossRef]
238. Sarmadi, M.; Karimi, N.; Palazón, J.; Ghassempour, A.; Mirjalili, M.H. Improved Effects of Polyethylene Glycol on the Growth, Antioxidative Enzymes Activity and Taxanes Production in a Taxus Baccata L. Callus Culture. *Plant Cell Tissue Organ Cult. PCTOC* **2019**, *137*, 319–328. [CrossRef]
239. Thilip, C.; Mehaboob, V.M.; Varutharaju, K.; Faizal, K.; Raja, P.; Aslam, A.; Shajahan, A. Elicitation of Withaferin-A in Hairy Root Culture of Withania Somnifera (L.) Dunal Using Natural Polysaccharides. *Biologia* **2019**, *74*, 961–968. [CrossRef]
240. Chung, I.-M.; Rekha, K.; Rajakumar, G.; Thiruvengadam, M. Production of Glucosinolates, Phenolic Compounds and Associated Gene Expression Profiles of Hairy Root Cultures in Turnip (Brassica Rapa Ssp. Rapa). *3 Biotech* **2016**, *6*, 175. [CrossRef]
241. Moharrami, F.; Hosseini, B.; Sharafi, A.; Farjaminezhad, M. Enhanced Production of Hyoscyamine and Scopolamine from Genetically Transformed Root Culture of Hyoscyamus Reticulatus L. Elicited by Iron Oxide Nanoparticles. *In Vitro Cell. Dev. Biol.-Plant* **2017**, *53*, 104–111. [CrossRef]
242. Gabr, A.M.M.; Mabrok, H.B.; Ghanem, K.Z.; Blaut, M.; Smetanska, I. Lignan Accumulation in Callus and Agrobacterium Rhizogenes-Mediated Hairy Root Cultures of Flax (Linum Usitatissimum). *Plant Cell Tissue Organ Cult. PCTOC* **2016**, *126*, 255–267. [CrossRef]
243. El-Ramady, H.; Faizy, S.; Amer, M.M.; Elsakhawy, T.; Omara, A.E.-D.; Eid, Y.; Brevik, E.C. Management of Salt-Affected Soils: A Photographic Mini-Review. *Environ. Biodivers. Soil Secur.* **2022**, *6*, 61–79. [CrossRef]
244. El-Ramady, H.; Brevik, E.C.; Elsakhawy, T.; Omara, A.-D.; Amer, M.; Abowaly, M.; El-Henawy, A.; Prokisch, J. Soil and Humans: A Comparative and A Pictorial Mini-Review. *Egypt. J. Soil Sci.* **2022**, *62*, 2. [CrossRef]
245. Brevik, E.C.; Omara, A.E.-D.; Elsakhawy, T.; Amer, M.; Fawzy, Z.F.; El-Ramady, H.; Prokisch, J. The Soil-Water-Plant-Human Nexus: A Call for Photographic Review Articles. *Environ. Biodivers. Soil Secur.* **2022**, *6*, 117–131. [CrossRef]
246. Fawzy, Z.F.; El-Ramady, H.; Omara, A.E.-D.; Elsakhawy, T.; Bayoumi, Y.; Shalaby, T.A.; Prokisch, J. From Farm-to-Fork: A pictorial Mini Review on Nano-Farming of Vegetables. *Environ. Biodivers. Soil Secur.* 2022; 6, *in press*.