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Causes and Conditions for Reduced Cultivation and Consumption of Underutilized Crops: Is There a Solution?

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Abstract: Underutilized crops are described as plant species that were once popular but have since been neglected by mainstream agriculture for several reasons. A widespread monoculture agricultural revolution and a tendency toward more high-yielding varieties were the main reasons for the underutilization of certain crops. Remarkably, underutilized crops have endured even without formal support, which indicates that besides their exceptional nutritional value and beneficial effects on human health they contain desirable traits that could be useful for building resilience and adaptation to climate-changing environments. As such, the re-establishment of these plants to the global food system is desired. To find solutions for overcoming the obstacles for the reintroduction of these crops and to bring the neglected species back to cultivation and utilization, a comprehensive understanding of the potential reasons for the reduced cultivation of these crops is necessary. In this article, potential reasons, causes, and conditions for the decreased cultivation and consumption of certain crops are discussed with a presentation of case studies of the following species: buckwheat, lentils, green leafy vegetables, sow thistle, grass pea, cucumber melon, and eggplant. Finally, potential solutions for overcoming the identified obstacles associated with both the cultivation and consumption of certain underutilized crops and neglected species are provided. Documented benefits of the production of various crops in agricultural production systems and the beneficial effects of increased consumption of these crops for human health should stimulate and encourage people from various disciplines, i.e., farmers, researchers, agronomists, nutritionists, and policymakers to join the efforts to bring neglected species back to cultivation and consumption.

Keywords: underutilized crops; reduced consumption; forgotten plants; orphan species; diversity

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1. Introduction

Neglected and underutilized species (NUS), also referred to as 'orphan' species are defined as: 'non-commodity wild or cultivated plant species, including crop wild relatives, that were once popular but have since been neglected by mainstream agriculture due to a range of agronomic, genetic, economic, social, and cultural reasons' [1]. Orphan species are predominantly grown on farms in resource-poor countries. Crops were primarily produced by women, who utilized the seeds on small landholdings in specific agro-ecological places and on peripheral and sub-peripheral lands to supply families with high nutritional value food [2]. These plants were also used as animal feed and in other agricultural products, producing income for resource-poor farmers [3]. However, due to their lack of economic importance, most of these plants have been abandoned by the international scientific community and industry when compared to products such as rice, wheat, and maize. The majority of these crops are usually marginalized or completely neglected by breeders, farmers, researchers, and policymakers. Additionally, what often happens is that a plant well-recognized as a main crop in one country at the same time becomes a neglected minor crop in another country [4].

Over recent years, consideration devoted to underutilized and neglected crops/plants has increased due to their known potential to diminish risk in agricultural production systems, improve human nutrition and health, generate income, strengthen ecosystem health, and support cultural diversity [1]. Before we can bring the neglected species 'back to a plate', we need to find out the most important reasons that explain their neglect and suggest possible solutions for overcoming the identified reasons for neglect.

In this article, potential reasons, causes, and conditions, for abandonment of certain NUS are discussed, together with a presentation of case studies of the following species: buckwheat, lentils, green leafy vegetables, sow thistle, grass pea, cucumber melon, and eggplant, which presents cases for more species not included in this review. Selected crops, plants of interest, represent various types of crops—cereals, grain legumes, fruits, vegetables, wild crops.

The main reasons for the reduced consumption and cultivation of crops of interest are identified and summarized. Finally, based solely on the presented data, potential solutions for overcoming identified obstacles related to both cultivation and consumption of some beneficial underutilized crops and neglected species are suggested.

2. Causes and Conditions for Reduced Cultivation of Certain Plants

There are about 30.000 edible plant species discovered worldwide, of which only 7.000 are cultivated for food [5,6]. At the moment, less than 150 species are commercially produced and around 100 crops provide close to 90% of the calories in the human diet [7]. More than 40% of our daily calories come from three staple crops: rice, wheat and maize. Four crops account for about half of global primary crop production: sugar cane, maize, wheat and rice [5]. Hence, a significant number of plant species remain underutilized.

Underutilized crops (also termed neglected, promising, orphan, minor, or little-used) are usually semi-domesticated, wild species tailored to local environments. When more productive crops turn out to be more easily attainable in farming systems, many traditional foods, that were used for centuries before it was abandoned. Agro-technical, institutional, policy perspectives and socioeconomic factors contributed to their underutilization. An extensive monoculture, agricultural modernization and inclination toward more high-yielding varieties were the main reasons for the underutilization of certain beneficial plants [4].

Conventional agriculture prefers monoculture. Simplified cropping systems and the high input high output model, which reduces biodiversity, makes farming more susceptible to environmental shocks and leads to a global ecological imbalance. Since the 1900s, more than 75% of genetic diversity has been lost [8]. This further leads to the dependence on a few staple crops and created a threat to food security, unbalanced diets, and ultimately the malnutrition of most vulnerable populations such as children, women, smallholder farmers, and indigenous people that depend on these traditional crops for food [9]. Extreme monoculture reduced genetic differences within varieties.

Politically, governments give priority to the production of high-yielding crop plants and provide subsidies for major crops only. A few major crops take over national and international markets and government policies. The Green Revolution focused on several major crops only. All other traditionally used species become marginalized, despite their important pro-livelihood and adoptive characteristics [10]. The lack of a natural environment favorable to production, processing, distribution, marketing, and consumption added an extra burden to the existing problem [7]. Therefore, both political and economic causes resulted in the rapid loss of traditional crops before they were even fully described, researched, and promoted. As a consequence, underutilized plants become under domesticated and were produced in home gardens or on small blocks of land, with a restricted opportunity to make improved landraces or ecotypes [4].

The production of NUS has been overlooked and ignored in agricultural research for various reasons, but the main reason was the low yield of underutilized varieties. Underutilized crops had no organized value chains and they were not incorporated in agricultural systems, so their production remained limited [11]. With the routine underestimation of wild foods comes the threat of neglecting the provisioning ecosystems and supporting local knowledge practices that maintain these food chains [12]. A drastic example of the devastating effects of concentrating solely on yield was Irish potato production, where one variety of potato was grown for years because of its much higher yields than other grains, leading to the starvation and the death of 1.5 million people [13]. Most importantly, due to reduced cultivation, underutilized crops lost genetic diversity, and imposed plants to various pests, diseases and abiotic stresses [14].

Moreover, yield estimation for NUS is not straightforward due to poorly developed research agendas, broad diversity within and among crop species and several phenological processes occurring simultaneously [15]. The yield data for NUS is limited, not easily available and mainly presented in grey literature sources [16].

An additional obstacle is the climate background that likewise changes. Alterations in temperature and rainfall patterns disturb traditional agriculture systems that demand relatively uniform conditions. Thus, traditional farming systems in marginal and remote areas turn out to be affected by these changes [1].

Stigmatization, a negative image of 'food of the poor' was an extra factor that led to reduced production and consumption of certain crops. Traditional and wild relatives of crops were often seen as old-fashioned and linked to the rural poor, especially in the eyes of recently urbanized populations in developed countries [8]. Furthermore, forgotten plants remain forgotten as people are uncertain of how they can be used as food [8]. Some of the reasons that these foods are disappearing are the following: demographic shift complemented by dietary changes, the long preparation time and advanced age of people who knew how to prepare these foods, limited supply of the forgotten foods and lack of innovative postharvest and processing technologies [1,6,17,18].

However, the value placed on conventional medicines and health remedies increased the requirement for these plants. The majority of plant species gathered from the wild are believed to be scarce herbal medicinal plant species and, as such, there is a need for some of these plants to be more commonly cultivated and utilized [4]. Agrobiodiversity is a crucial element of sustainable agriculture. Forgotten plant crops are the key components of such a system that could be used to meet increased food requirements worldwide [19]. Underutilized crops have endured even without formal support, which implies that they contain some desirable traits that could be useful for building resilience and adaptation to climate-changing environments [19]. The utilization of orphaned crop cereal species, more resistant to certain climates and environments, is crucial in agronomic crop productivity in terms of both nutrient quality and yield [9].

3. Examples of Neglected and Underutilized Crops

The following species were selected to be presented in this article: buckwheat, sow thistle, grass pea, eggplant, snake melon, lentils, and green leafy vegetables. Selected crops describe different types of crops—cereals, grain legumes, fruits, vegetables, wild crops. For example, buckwheat was taken as an example of a cereal with reduced cultivation practices in certain countries, but the general results for the reduced production of this plant could be applied to all other plants in the cereal category (proso millet, quinoa, sorghum, etc.).

3.1. Buckwheat

The origin center for buckwheat cultivation was Middle Asia, later transferred to Central and Eastern Europe by nomadic people [20]. In Europe, buckwheat gained a reputation as a valuable crop and was extensively used within the 13th century in Italy, Germany, and Austria and it remained extremely popular until the early 20th century. However, due to the cultivation and expansion of other cereals, specifically common wheat (*Triticum aestivum* L.), buckwheat slowly lost its importance and become a neglected plant [21].

Many different species of buckwheat are grown worldwide, but only a few are used as food. These include: Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.), common buckwheat (*Fagopyrum esculentum* Moench.), Jammu and Kashmir coarse buckwheat (*Fagopyrum sagittatum* Gilib), and Kashmir buckwheat (*Fagopyrum kashmirianum* Munshi) [22–24].

The cultivation of buckwheat is convenient and with strong potential, as it demands minimal resources and can be grown in poor and marginal soils [25]. A short period of growth and the ability to be sustained in any climatic environmental stress situation are contributing additionally to the self-compatible nature of buckwheat [20]. Yet, due to the tightly adhering hull and bitter taste, buckwheat became a minor crop in many European countries except for Ukraine, Poland, and the Russian Federation [26].

Numerous factors prohibit extensive cultivation and inclusion of buckwheat into the modern food system: agronomic factors (growth, yield), technological (processing of seeds, genetic factors), social (lack of awareness low esteem), as well as economic (marketing restraints) [16]. The lack of focused crop improvement efforts compared to major cereal crops is a constant downfall for more common buckwheat production. Strong self-cross incompatibility inhibits traditional breeding attempts [19]. The indeterminate growth, low seed sets, unsynchronized flowering, imperfect reproductive organs, failure of fertilization, and susceptibility to both spring and fall colds are well-known obstacles to the cultivation and consumption of this valuable plant [12,19]. Furthermore, the existence of allergenic compounds impedes buckwheat recognition amongst the farmers [17]. Consequently, farmers lost interest in cultivating buckwheat and turned their attention to cereals that could provide extra yield and additional profit; that is, wheat, maize, and rice. The growing human population and an increased need for food security and economic stability leads to technological interventions intended for the cultivation of high demanding crops [20].

Agronomic drawbacks are one of the major obstacles that hinder the widespread production of buckwheat. There is an insufficiently characterized agronomic evaluation of buckwheat plants compared to newer crops [27]. On-farm management of buckwheat germplasm has been initiated worldwide. However, comprehensive reports regarding the same are still scarce apart from studies in South-West China and the Indian Himalayan region [20].

The knowledge of the yield, production and additional quality traits of buckwheat mainly comes from low-input systems, which restricts our ability to measure its actual potential [20]. Similarly, there are certain limitations at the genomic level, for instance, self-incompatibility in buckwheat that reduces its breeding and trait enhancement. Seed shattering and flower abortion limit buckwheat grain yields [28]. Furthermore, transformation and mutagenesis have not yet been established or adjusted, so there is still a dependence on natural variations for breeding purposes.

Buckwheat has an immense nutraceutical potential, but the term 'underutilized crop' is still associated with it due to the reasons discussed in the previous paragraphs. There are several improved varieties of buckwheat that could be sustained under wide environmental conditions. The desirable agronomical traits of buckwheat that should be enhanced are seed size, resistance to seed lodging and shattering, maturity as well as an easier dehulling [29]. In addition, buckwheat is known as a gluten free pseudo-cereal that contain protein of high nutritional value [30].

The higher demand for gluten-free diets experienced during the last few years helps in bringing this and similar plants back to cultivation. The nutritional and health benefits of buckwheat should be promoted and with increased awareness of its potential advantages, the cultivation and consumption practices of buckwheat could increase exponentially.

3.2. Sowthistle

An interest in growing sow thistle or the so-called 'wild edible greens' varies from place to place, from one country to another. Generally speaking, for the Asteraceae family to which sow thistle (*Sonchus oleraceus* L.) belongs, certain information is offered on their agronomic practices related to harvesting, fertilization regimens, growing period, cropping under different environmental conditions, and cultivation systems [31–34]. Plants can survive and reproduce on the bare sides of chalk or other cliffs, or on saline soils, but they thrive best on fertile soils [35]. A detailed datasheet on *Sonchus oleraceus* was provided recently by [33].

Sow thistle has become a serious weed and a much bigger problem with the gradual shift from conventional to conservation farming systems [36]. In certain parts of the world, such as Canada and Australia, it is often referred to as a noxious weed [33]. Therefore, additional work is needed to establish potential ways to control the yield of these crops without losing the food safety and nutritional quality of the final products, as most of these species are grown in the wild or encountered as weeds within the field [33,37].

In summary, sow thistle provides promising solutions toward sustainability and increased agrobiodiversity, as it is tolerant to arduous conditions and can be adapted easily to climate changes [33,38]. These foods are used as an integral part of local cuisines, and for medicinal purposes in areas where they grow, in Africa and Asia, where they are also used for feeding cattle and other livestock [33,39]. Sow thistle is present in almost all countries worldwide, but it is widespread in China, Romania, and the United States [33]. The commercial cultivation of such species has attracted the attention of both farmers and consumers due to the potential of using wild edible species in sustainable systems to produce high value-added products with beneficial health effects [31].

3.3. Grass Pea

Grass pea (*Lathyrus sativus* L.) is one of the oldest cultivated crops, with a prolonged history of domestication. It is a typical orphan legume crop [40]. The seeds were found in the oldest excavations in India and Turkey in 8000 b.c. and later in the Balkan region in 8000 b.c. [2]. Grass pea was present in the funeral offerings found in the Egyptian pyramids, and it was considered a special food offered to kings. Soon after, these crops were spread to the temperate Mediterranean region and further to tropics and sub-tropic regions in the northern hemisphere, South Asia, East Africa, and South America [41]. Food prepared from grass pea has been very popular in South Asia (Nepal, India, and Bangladesh), many European countries (Italy, Spain, Portugal, Poland, and France), and in Africa (Ethiopia) [2].

However, today, grass pea is almost an entirely forgotten plant produced in very small quantities, and mainly used during some religious celebrations [40]. In addition, the reputation of grass pea has changed substantially, and grass pea is often seen as a subsistence food for the poorest of the poor [41]. Abandonment in cultivation and production caused a lack of genetic improvement, which contributed to reduced yield in terms of both quantity and quality [40].

Neurolathyrism, a neurodegenerative syndrome resulting in the paralysis of lower limbs, has been associated with the consumption of grass pea seeds [41].

The disease is caused by the presence of a neurotoxin in these plants, β-*N*-oxalyl-L-α,β-diaminopropionic acid (β-L-ODAP), also known as Noxalyl-amino-L-alanine (BOAA) or dencichine [42].

Therefore, the cultivation of this crop was a source of discussion between agricultural scientists, farmers, and nutritionists for decades due to its bad reputation as a toxic plant. However, while, a negative connotation of 'lathyrism' has existed since 1873, the disorder occurs only when the primary component makes 30% of the total caloric intake, and when grass pea is consumed as a sole food for more than three to four months [43].

β-L-ODAP is found in all parts of the plants, with the highest concentrations measured in the embryo at the reproductive stage and in the leaf at the vegetative stage [43]. A lack of appropriate assays to screen large populations of grass pea accessions or mutants restricts the development of low-β-L-ODAP varieties [42].

The main convenience of grass pea lies in its tolerance to abiotic stresses, i.e., flood, waterlogged, salinity, and drought [2]. Despite enormous achievements and rapid advances in genome sequencing technologies, particularly, next generation sequencing, genomic information related to grass pea is still missing [44]. So far, very limited research has been carried out towards identifying possible ways for reducing the presence of b-ODAP and improving the nutritional content of this legume plant [45].

3.4. Eggplant

Eggplant (*Solanum melongena* L.) is referred to as an 'old world crop' domesticated in Asia, Africa, and Europe. Archeological evidence indicates that the utilization of wild eggplants was initiated in India and later in China, with a consequent additional and distinct center of domestication in the Philippines. During the eighth century, eggplant spread westward alongside the Silk Road into Western Asia, Europe and Africa, and eastward to Japan. Likewise, the plant was introduced into the Americas shortly after Europeans arrived there and soon after expanded into other parts of the world. The name was probably derived from the white egg-like fruits [46].

These days, eggplant is mostly used in Africa, the subtropics (Bangladesh, India, Central America), Southeast Asia, and the Middle East. It is also nurtured in several warm temperate areas such as the Mediterranean and Southern USA. Among the Solanaceae vegetables (tomatoes and peppers, including potatoes) eggplant is ranked third and fourth in terms of total production and area harvested, respectively [47].

Solanum is a large genus with over 1400 species, among which some members are poisonous to humans, for example, the nightshades (*S. dulcamara* L.). There is one well-cultivated eggplant species, known as brinjal or aubergine, and two other underutilized eggplant species, the African eggplant (*S. macrocarpon* L.) and the scarlet eggplant (*S. aethiopicum* L.), cultivated with local significance [48]. The domestication of species cultivated in Africa, i.e., the gboma eggplants and scarlet eggplant is less known [49].

Eggplant has a rather long growth period, so it is more exposed to a wide-ranging array of plant diseases (i.e., bacterial wilt, anthracnose fruit rot, fusarium wilt, verticillium wilt), weeds, pests (i.e., mites, whiteflies, aphids) and nematodes compared to other vegetables [50]. Yield and fruit quality is reduced by unpredictable weather conditions with extreme temperatures, drought, or flooding [49].

The leaves and fruits are most commonly used for food and medicinal purposes. However, little progress has been made in the breeding of cultivated eggplants, based on the information obtained from wild species, mainly due to the lack of information on genome sequences [48]. The wild relatives are regularly major sources of biotic and abiotic tolerance alleles, so they should be used whenever possible. The progress of genome-anchored markers necessary for successful trait transfer using marker-assisted collection in this case was precluded by the absence of a genome sequence for wild relatives. Improved eggplant varieties are needed for sustainable manufacturing and adaptation to climate changes [49,51,52].

3.5. Snake Melon

The cucumber–like and extremely long snake melons (*Cucumis melo* var. *flexuosus* (L.) Naud.) are featured in 3000-year-old Egyptian mural paintings [53].

Snake melon is identified in the bible as a vegetable consumed by the Hebrews in Egypt [54]. Extensive documents on the use of snake melons are found in ancient Chinese writings from about 2000 bc., and Roman and Greek documents from the first century bc. [55,56]. Two snake melons are depicted in the festoons in the Villa Farnesina in Rome at the beginning of the sixteenth century [57].

Sweet melon forms were not known in the Roman time and were introduced from Persia or the Caucasus by travelers, making their arrival in Europe around the 13th century [54]. Snake melon is not a cucumber (*Cucumis sativus* L.), but rather a variety of muskmelon, also known as yard-long cucumber or Kakdi. It is considered to be native of Armenia, or somewhere nearby, such as Iran. The fruits can grow to 36 inches long, and they do taste similar to cucumbers [54].

Although melon is a neglected crop, snake melons are still frequently cultivated in many African, Asian, and Mediterranean countries, known by different local names such as Armenian cucumber, Cucumaru, Hiti, Fakous, Kakri, or Mekte [55].

Many local landraces have been conserved in Spain, mainly in eastern coastal regions (Murcia, Valencia, Alicante), and are used for self-consumption [35,58,59]. This nonaromatic fruit is long nonsweet usually eaten as pickled or fresh vegetables. They are used like cucumbers in many traditional recipes due to their appearance and taste and are also utilized as conventional medicine [55]. The short shelf life of the fruits, much shorter than that of the cucumbers, limits their commercialization in remote markets. In addition, this crop is threatened by harsh genetic erosion [54]. Melons genotypes vary in quality and productivity driving traits such as total yield, resistance to main pest diseases (i.e., powdery mildew), and number of fruits per vine [60]. Fungal diseases are similarly affecting both open field and greenhouse-grown plants. While fungal species produce more virulent strains, breeders and farmers are trying to find ways to grow more resistant melon genotypes [35,61–63]. Several limiting factors for snake melon organic farming need to be resolved to be economically sustainable. For example, reduced yield and yield stability. Pests and diseases are additional factors contributing to the loss of productivity, and the application of agrochemicals is inadequate. An additional challenge is the fact that the local production is confined to marginal lands where abiotic and biotic stressful conditions arise [55].

3.6. Lentils

Cultivated lentil (*Lens culinaris* Medic.) was initially domesticated in western Asia around 2000 bc., and after that it was spread to Egypt, southern and central Europe, the Mediterranean, Pakistan, China, Ethiopia, India, Afghanistan, later to Latin America, Argentina, Colombia, Mexico, and finally to Canada [64]. Lentils offered a cheap source of dietary proteins to rural and urban families in ancient times [65].

Nowadays, lentil is an important pulse crop cultivated in most subtropical regions, the Indian Subcontinent, Southern Europe, Middle East, North and South America, Northern Africa and East Africa, Australia, and West Asia. Its production accounts for 27% of the total crop production worldwide [66]. The USA, Nepal, China, and Ethiopia, Turkey, Australia are the major lentil growing countries in the world. The major sites of the increased global production are India and Canada [64].

Besides being important for feeding the human population, lentils are valuable for providing beneficial ecosystem services such as green manuring, atmospheric nitrogen capture, and the maintenance of soil fertility [67,68]. Lentils are cultivated and consumed in many European countries, but in different ways. Regional food habits and traditions determine the consumption patterns of lentils [65].

However, lentils are still considered as neglected and underutilized crops. Legume yield capacities have been limited because of its demotion to marginal lands where numerous abiotic stresses frequently occur, for instance, short growing seasons, poor soils, and water limitation [66]. As lentil plants have weak stems and an undefined growth rate, they are often grown alongside a companion crop.

Monocropping systems often used in the dry regions of the Mediterranean are not the most beneficial for cultivation of lentils [69–71]. The farming of lentils is complex in comparison to other crops. A successful mixed system cultivation of lentils and companion crops, usually cereals, is affected by many factors [72]. The relations between lentils and their companion crop can be both negative and positive [73].

Lentil production in humid areas is also challenging, as heavy rain causes the frequent lodging of lentil plants, reduces the plants' distance to the ground, and consequently the grain yield of local lentil farmers, which is in most cases low [73].

Therefore, the cultivation of lentils was reduced over time due to the increasing superiority of other crops, such as cereals, that could be grown on marginal land and benefit from chemical-synthetic crop protection and application of mineral fertilizers. As lentils lost their economic significance, breeding of high-performance lentil varieties appropriate for humid climates stopped. Based on the Statistical State Office of Baden-Württemberg data in Germany, the cultivation of lentils in Germany had almost completely vanished by the middle of the 20th century [73]. Local cultivars had low yields and were very susceptible to several stressors and diseases. The production was affected by both biotic (weeds, diseases, insects) and abiotic (drought, soil fertility, and temperature) stressors [64]. Likewise, low grain quality was also evident, small-seeded, unsought color, and low plumpness seeds were produced [39,42,74,75].

Additional yield-reducing factors are slow to leaf area development, lack of seedling vigor, high rate of flower drop, low harvest index, low pod setting, low or no response to inputs, and lack of lodging resistance [64]. The time-demanding processes for cleaning, separating, and drying made lentil cultivation less appealing in comparison with their companion crops. Furthermore, disease is a major threat to lentil production, which, at times, produced a total crop failure [73]. Rust, Fusarium wilt and root rots are the major diseases of lentil plants [39]. In Ethiopia, a new variety of lentils for the low land dry areas have been developed but again, it was not always possible for researchers to provide these varieties to farmers worldwide as Ethiopian farmers like to keep their seeds. In addition, due to an increased incidence of disease and insect problems, a small percentage of growers (below 10%) adopted new and improved varieties [41].

The development of more disease resistant varieties for the cultivation of lentils should increase the willingness of farmers to grow and cultivate lentil crops. Ethiopian farmers should be encouraged to share and increase cultivation of locally invented varieties of lentils. This positive trend of producing new varieties should be continued in the future and expanded to other counties world-wide.

3.7. Indigenous Green Leafy Vegetables

A wide range of wild varieties of leafy vegetables, tubers, roots, fruits, and stems are harvested for their taste and health benefits, cultural uses, as food supplements, or to tide over food shortages. These plants are an integral part of local food habits, useful in ensuring household food and income security. Leafy vegetable plants are an important dietary component, rich in several different vitamins such as folic acid, vitamin C, vitamin A and minerals, i.e., potassium, magnesium, iron, zinc, and calcium. Green leafy vegetables contain health promoting phytochemicals, known to have an important role in alleviation and fighting against many deficiencies and diseases [76]. The consumption of vegetables has been associated with a decreased risk of developing various diseases including heart ailments and malignancies, pointing out the benefits of their increased intake [77].

The taste, bitterness, and absurd tastes and smell were among the main reported issue for reduced consumption of underutilized vegetables. The decline in their production and consumption among various communities is to an extent due to the introduction of exotic vegetable varieties that are more affordable, grown without fertilizers or pesticides, organically, and can be used not only as a food but also as medicine [76].

New exotic varieties did not have a negative connotation linked to them; they were not considered primitive foodstuff or a poor man's diet. Those who consumed underutilized varieties were often perceived as old-fashioned and primitive [8].

Short shelf life and quick deterioration in quality, flavor, and nutritional content were additional reasons for the poor utilization of some forgotten green leafy vegetables. The inability to maintain freshness for longer periods was a major obstacle for farmers who wanted to increase marketing opportunities and capacity to advertise and sell underutilized vegetable species [76]. Further work should be devoted to identifying potential ways for overcoming the obstacles related to the taste and smell of these foods and invest in recognizing innovative ways of preparation and cooking that will minimize the unpleasant characteristics.

4. Summary of the Major Findings

The main reasons for the reduced cultivation and consumption of crops of interest (Figure 1) can be categorized into several groups: agronomic, social, technological, economic, and political. The most important identified factors are listed below:

- Problems with production and harvesting, yield, land usage, seed availability, processing of seeds
- Biotic factors: insects, diseases, and weeds
- Abiotic issues: temperature, soil fertility, waterlogging, drought
- Presence of toxins and allergenic compounds
- Agronomical traits, germplasm collection, genetic factors, the limited number of species used as a food
- Poor economic attractiveness of underutilized crops in comparison to staple crops
- Green revolution issues, self-incompatibility of certain plants
- Absence of genome sequences for certain crops
- Inefficiency in producing, processing, and storing these crops
- Non-existent or disorganized food supply chains
- Expansion and cultivation of more common higher yield cereal crops, monoculture
- Increased cultivation of so-called 'exotic' varieties
- The lack of sound baseline data on the nutritional and health-protective/promoting properties of these foods
- Lack of cooking skills for the preparation of foods based on these plants
- Unaccustomed taste of the foods, non-popular recipes
- Negative assumptions about a poor rural lifestyle and low social status, negative cultural stereotypes against these traditional foods, such as "this is what poor people eat"
- The lack of policy recommendations
- Marketing constraints, short shelf life
- Various political and economic reasons.

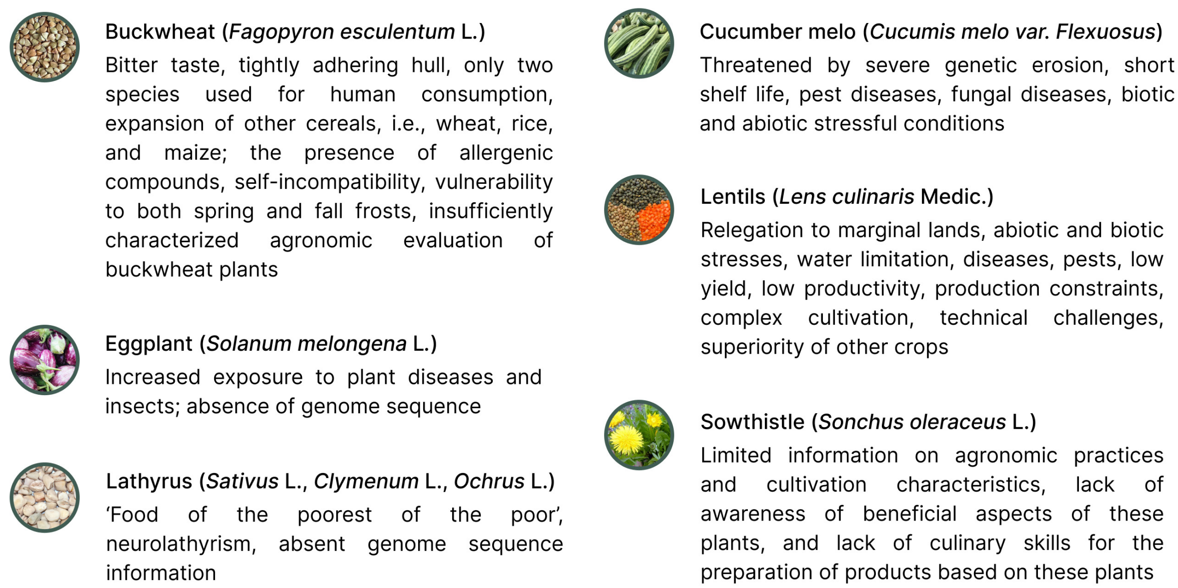

Figure 1. The most important identified factors for altered or reduced cultivation and decreased consumption of selected underutilized crops.

5. Enhancement of Underutilized Crops and Government Policies

The significance of NUS becomes more extensively recognized by the global scientific community and different modeling studies have been performed over the years. The development of models that stimulate growth, resource use and yield for a broader range of NUS is emerging [16]. The potential for high level improvements exists, providing the enhancement to adaptability, quality, and yield of these crops. For example, the introduction of quinoa in breeding programs enhanced its yield and quality traits and stimulated expansion of seed production systems and post harvesting preservation [78]. Similarly, the improved productivity of finger millet was achieved with better education, technical support and improved growing practices that subsequently increased yield [79]. Grass pea is often referred to as an insurance crop in areas prone to abiotic stresses, as it can generate consistent yields when all other crops fail due to drought [80]. New varieties that combined low β-ODAP with high-yield potential and resistance to a range of biotic and abiotic stresses are developed [81]. The inclusion of lentils in various cropping systems enhanced the physical properties of soils and increases the yield of consequent crops [70]. Potential ways for increasing the yield of sow thistle were also identified [82].

Nowadays, the European Commission offers various income subsidies for farmers [83]. The Breakthrough Crop Challenge is part of FFAR's Harvest for Health initiative, which aims to accelerate the development of underutilized crops with the aim of enhancing the diversity of nutritious foods in the marketplace [84]. Likewise, greening is another example of a European program that supports crop diversification [85]. There are also other schemes that support farmers to produce specific crops to prevent problems that could arise from the abandonment of production of certain varieties and reduced biodiversification. New farming policies and disbursements in England stimulate farmers to increase farmland biodiversity [86]. Similarly, the Japanese government provides subsidies to farmers who grow buckwheat with the aim to decrease excessive rice production [87,88]. High-yielding buckwheat varieties were developed and new varieties with high rutin content were recently developed in Japan [87]. In South Asia, enormous progress has been made in lentil crop production. The changes in manufacture reduced yield gaps by 65 to 75% in farmers' fields because of improved lentil genetics and production, better crop management, enhanced plant architecture and reduced post-harvest losses [78]. High yielding lentils cultivars with enhanced concentrations of iron and zinc have been released in Bangladesh [89].

6. Potential Solutions and Recommendations for Overcoming Identified Barriers

Based on the data provided within this review, several different strategies can be proposed as potential solutions for the partial or total overcoming of some of the detected obstacles:

1. Use beneficial crop traits for producing more environmentally friendly and fewer stressor-affected crop varieties;
2. Diminish problems with production, seed availability, harvesting, and processing of underutilized crops;
3. Enhance the desirable agronomical traits of certain plants as much as possible (i.e., seed size, resistance to various pests and diseases);
4. Develop adequate assays for investigation and elimination of potentially toxic and allergenic substances found in certain crops;
5. Apply novel rapid technologies for the identification of genome sequencing data of neglected species;
6. Design appropriate and country-specific policy recommendations for the cultivation of forgotten plants;
7. Address existing negative connotations and educate consumers and increase awareness of the nutritional benefits of underutilized foods and products;
8. Enhance knowledge on the cultivation and consumption practices of sow thistle and related species to ensure their broader implementation and utilization;
9. Implement additional research towards better understanding the genomic sequence of grass peas, identifying potential ways to produce low-level b-ODAP plants and incorporating this protein-rich plant into more common cultivation and consumption;
10. Aim for current eggplant breeding programs to be oriented towards the development of higher-yielding varieties with high fruit quality, shelf-life, and resistance to most

important disease and insect pests, with a wide-ranging adaptation to environmental stresses;
11. Develop more disease resistant varieties for the cultivation of lentils that will increase the willingness of farmers to grow and cultivate lentil crops. This positive trend should be continued in the future and expanded to other counties worldwide;
12. Invest towards identifying the most suitable storage arrangements that will ensure maximum conservation of the nutritional potential of green leafy vegetables;
13. Promote the cultivation of snake melon and improve plant diversity with an aim of providing nutritionally rich cultivars with distinct health benefits;
14. Encourage plant-based diets and create programs for advertising underutilized foods of interest, encourage their use in everyday cooking, promote their use as both food and medicine, and stimulate improvements of culinary skills of consumers;
15. Include the principles of healthy diets and sustainable food consumption in public health programs to raise awareness towards healthier and more environmentally friendly food consumption;
16. Limit the demand for increased food production by adopting healthier diets and reducing food waste, as well as limiting the consumption of other material goods and services that affect biodiversity, such as forestry, energy, and fresh water supplies;
17. Use the food system approach for policymaking and decrease taxes on environmentally friendly foods;
18. Reduce political and economic neglect of underutilized species as much as possible.

Policies that promote underutilized crops should be empowering, regenerative, productive, and prosperous to redesign the underlying assumptions related to reduced cultivation and consumption of underutilized crops. Measures based on the reintroduction of underutilized crops that ensure more sustainable and biodiverse food systems, while addressing agricultural, climate and ecosystem issues are required. Policies that support the interconnections of different disciplines and improved coordination among systems and sectors will provide room for more productive and resilient food systems. Nutrition driven agricultural production will increase the availability of fresh, diverse locally grown fresh fruits and vegetables and encourage healthy plant-based diets. Context-specific policy solutions should be created to address various problems for the reintroduction of forgotten plants to the food system. Active governance is necessary to support policy shifts, multilateral coordination and cooperation, effective multi-stakeholder coalitions and international partnerships.

7. Conclusions

Neglected and underutilized crops are often described as plant species, including wild relatives of crops, whose production has been reduced by conventional agriculture for a variety of agronomic, genetic, economic, social, and cultural reasons. This review summarizes the main reasons and conditions that contributed to the reduced cultivation and consumption of certain forgotten and underutilized plants. The focus was on seven crops, each describing different types of crop plants: buckwheat, sow thistle, grass pea, eggplant, snake melon, lentils, and green leafy vegetables. The common reasons for the reduced production of these plants could, at least to a certain degree, be applied to all other plants within the same category.

Once the main obstacles were identified, different strategies were proposed as potential solutions for the partial or total overcoming of some of the challenges. Better integration of a wide range of underutilized crops into agricultural and food systems is needed to ensure greater food diversity and increased environmental sustainability.

The recognized benefits in reducing the identified risks to the production of various crops in agricultural production systems and the potential benefits of increased consumption of these crops for human nutrition and health should be the primary drivers that will encourage farmers, breeders, researchers, agronomists, nutritionists, and policymakers to bring neglected species back to cultivation.

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