Sustainability **2014**, *6*, 319-335; doi:10.3390/su6010319

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Article

Potential of Underutilized Traditional Vegetables and Legume Crops to Contribute to Food and Nutritional Security, Income and More Sustainable Production Systems

Andreas W. Ebert

AVRDC - The World Vegetable Center, P.O. Box 42, Shanhua, Tainan 74199, Taiwan;
E-Mail: andreas.ebert@worldveg.org; Tel.: +886-6-583-7801 (ext. 530); Fax: +886-6-583-0009

Received: 21 November 2013; in revised form: 24 December 2013 / Accepted: 30 December 2013 / Published: 7 January 2014

Abstract: Agriculture is under pressure to produce greater quantities of food, feed and biofuel on limited land resources. Current over-reliance on a handful of major staple crops has inherent agronomic, ecological, nutritional and economic risks and is probably unsustainable in the long run. Wider use of today's underutilized minor crops provides more options to build temporal and spatial heterogeneity into uniform cropping systems and will enhance resilience to both biotic and abiotic stress. Many traditional vegetables and underutilized legume crops are an essential source of vitamins, micronutrients and protein and, thus, a valuable component to attain nutritional security. Vegetables in general are of considerable commercial value and therefore an important source of household income. Significant research, breeding and development efforts are needed for a range of promising crops to convert existing local landraces into competitive varieties with wide adaptation and promising commercial potential. Access to genetic diversity of these selected crops is a pre-condition for success. Three underutilized minor crops—amaranth, drumstick tree, and mungbean—are highlighted and briefly described. All three crops are well-represented in AVRDC's genebank with substantial inter- and intra-specific genetic diversity, and already have demonstrated their potential for wider adoption and commercial exploitation.

Keywords: underutilized traditional vegetables; food and nutritional security; income generation; sustainable production systems; climate change; crop diversification; amaranth; drumstick tree; mungbean

---

1. Introduction

Agriculture is under increasing pressure to produce greater quantities of food, feed and biofuel on limited land resources for the projected nine billion people on the planet by 2050 [1]. It is envisioned that agricultural production has to increase by 70% by 2050 to cope with an estimated 40% increase in world population [2]. Ninety percent of this growth is expected to result from enhanced cropping intensity and higher crop yields, while the remainder has to be produced on land currently not used for agricultural production. While this conservative estimate is the outcome of a 2009 expert consultation with regard to national and regional demand trends, another group forecast a 100%–110% increase in global crop demand from 2005 to 2050 based on quantitative global trends in per capita demand that emphasize income-dependent food choices [3].

As economies develop, there is generally an increased demand for calories and protein derived from animal products [4] and this can be clearly demonstrated by the dramatic rise in meat consumption in China, which increased by a factor of 5.5 in less than 20 years (from 1990 to 2009). China is now well above the 2009 average meat consumption worldwide and more than double the 2009 average meat consumption in Asia [5]. The increasing demand for animal products in the diet is a major driver for greater demand for pasture as well as for crops grown for animal feed. The low efficiency with which some types of livestock, especially cattle and pigs, convert crop calories and protein into edible food further aggravates this trend [1,6]. As expansion of pastures is difficult with limited agricultural land resources, livestock production might shift to more cereal intensive feeding technologies, thus further increasing world cereal feed demand well above the projections made by international organizations [3,4]. Furthermore, there is evidence that the production of biofuels from grain crops is another driver for stronger competition for land, water, and energy—resources that are vital for food production [7].

2. Crop Intensification *vs.* More Diverse, Sustainable Production Systems

The required growth of agricultural production could be achieved by following the current trend of greater agricultural intensification and yield improvements in developed countries and additional land clearing in poorer countries with lower agricultural output per unit area. This would lead to an increase of global land clearing of natural ecosystems to a total of about one billion ha by 2050, global agricultural greenhouse gas emissions to approximately 3 Gt per year of CO_2-carbon equivalents, and global N use to about 250 Mt per year [3]. The production gains would come at the expense of dramatic global environmental impact through a 2.4–2.7-fold increase in nitrogen- and phosphorous-driven eutrophication of terrestrial, freshwater and near-shore marine ecosystems and comparable increases in pesticide use [8]. Eutrophication and habitat destruction would lead to massive loss of biodiversity and ecosystem services and, consequently, loss of quality of life for mankind.

An alternative approach would be a moderate, sustainable intensification in existing croplands, especially in regions or countries with relatively low yields, and by closing the yield gap between potential and actual farm yield [1,9]. This can be achieved through the development of new technological improvements such as precision agriculture to optimize the use of inputs [10] and the adaptation and transfer of existing high-yielding technologies to low-yielding croplands. This approach would require a modest land clearing of 200 million ha by 2050, greenhouse gas emissions of one Gt per year, and global N use of 225 Mt annually [3].

Crop and livestock intensification is hardly possible without negative externalities—effects on the environment or economy that are not reflected in the cost of producing food. These effects include the release of greenhouse gases such as methane and nitrous oxide, which are more harmful to the environment than CO_2 [11]. Other negative effects include environmental pollution due to nutrient and pesticide run-off, water shortages due to over-extraction, soil degradation and the loss of biodiversity through land conversion, monocropping or inappropriate management. Ecosystems may also be disrupted by overexploitation of fish resources or extraction of other aquatic foods [12].

The Living Planet Index, which reflects changes in the health of the earth's ecosystems, declined between 1992 and 2012 by 12% at the global level and by 30% in the tropics [13]. The dramatic decline in the tropics is indicative of a severe degradation of biodiversity due to high deforestation rates of primary forest and transformation into agricultural land and pasture [14]. There are also fears that the current model of biodiversity governance and standardized biodiversity assessment and monitoring with a major focus on market-based instruments can lead to the marginalization of agroecosystems as essential habitat for biodiversity. Standardized assessments naturally find more value in "wild" areas given their larger numbers of endemic species [15]. Agriculture, agroforestry systems, pastoral lands and silviculture cover a major portion of the planet. These cultivated systems may have a major impact on conservation outcomes if properly considered and integrated into biodiversity governance. The recent focus on sustainable food systems requires the integration of agroecosystems, agricultural and associated wild biodiversity into overall biodiversity management schemes. Cultivated and associated wild biodiversity is the foundation of productive, sustainable and resilient food systems [16,17].

There are several ways to reduce the negative externalities of agriculture and to move towards sustainable intensification of crop production. Sustainability implies the use of resources at rates that do not exceed the capacity of the planet to regenerate them [1]. Juma and co-workers [18] list six sustainability measures for sustainable intensification of agriculture: (a) same or less land and water use; (b) efficient, prudent use of inputs; (c) minimized greenhouse gas (GHG) emissions; (d) increased natural capital; (e) strengthened resilience; and (f) reduced environmental impact. Sustainable intensification can thus be defined as *producing more outputs with more prudent use of all inputs—on a durable basis—while reducing environmental damage and building resilience, natural capital and the flow of environmental services* [19].

Net reductions in some greenhouse gas emissions might be possible by a more thorough adoption of integrated pest management methods, the integrated management of waste in livestock production, and the introduction and enhanced use of agroforestry systems. Soil conservation methods such as zero or reduced tillage, contour farming, and the use of mulches and cover crops will improve water retention and reduce soil erosion. However, these practices may not lead to increased soil carbon storage or to reduced emissions of nitrous oxide. Precision agriculture will be a useful tool towards sustainable agriculture by maximizing the use of inputs and minimizing waste and run-offs of nutrients and pesticides.

3. Crop Diversification

Only three crops—wheat, rice and maize—covered 555 million ha or 40% of all arable land globally in 2011 [3,20] delivering more than 50% of human calorie intake [4,20,21]. The 10 largest international seed companies, which control two-thirds of the global seed market, focus exclusively on major staple crops to ensure high returns on investments [20]. The lower license fees paid to the self-pollinating wheat crop makes this crop less attractive for breeders [9] and may lead to a further concentration on only two out of the three dominating crops [20].

Reliance on a handful of major crops has inherent agronomic, ecological, nutritional and economic risks and is probably unsustainable in the long run, especially in view of global climate change. It is now generally accepted that climate change will have a major impact on both biotic and abiotic stresses in agricultural production systems and threaten yield and crop sustainability [22]. Greater diversity, which builds spatial and temporal heterogeneity into the cropping system, will enhance resilience to abiotic and biotic stresses [23]. There are many examples of successful pest and disease suppression and buffering against climate variability in more diverse agroecosystems [24]. Diversified agroecosystems can be achieved in various ways: (a) through intraspecific genetic diversity in monoculture systems (of rice, for example); (b) increased structural diversity in monocultures by diversifying the plant age structure or strip-cutting fields so that natural enemies have a temporal and spatial refuge; (c) diversifying crop land by growing grass strips or vegetation banks between and alongside monocultures as a refuge for natural enemies; (d) temporal diversity can be achieved by rotating cereal crops with broadleaf and nitrogen-fixing crops; (e) crop diversification by growing compatible crop mixtures—two or more crop species—in the same field is reported to lead to disease suppression, climate change buffering and increased production; (f) growing crops and trees together in agroforestry systems provides spatial and temporal diversity; (g) development of larger-scale diversified landscapes at the farm or landscape level by integrating farmland with agroforestry, livestock and silviculture [22].

A recent study undertaken by Bobojonov and co-workers [25] in the Khorezm region of Uzbekistan, representative of the irrigated lowlands of Central Asia, looked at the options and constraints for crop diversification. Approximately 70% of the area in this region is used for irrigated cotton and winter wheat under a state procurement mandate. The diversification into other crops like sorghum (*Sorghum bicolor*), potato (*Solanum tuberosum*), indigo (*Indigofera tinctoria*), mungbean (*Vigna radiata*), and maize (*Zea mays*) could lead to sustainable agriculture in the irrigated areas of Central Asia by enhancing economic, ecological, and social conditions. Cropping system experiments conducted in the US Corn Belt revealed that the diversification of the dominant corn-soybean cropping pattern with small grains and forage legumes can result in a significant decrease in the use of agrochemicals and fossil hydrocarbons without having a negative impact on yield and profitability [26]. Other environmental benefits such as improved soil and water conservation, better nutrient retention, and higher populations of native plants and birds can be obtained by converting small amounts of crop land to natural mixed grassland buffer strips. Furthermore, the integration of native perennial plant species such as trees, different grasses and mixtures of multiple grassland species into the agroecosystem has two major benefits: it can generate large amounts of biofuel feedstocks and at the same time increase soil carbon storage and decrease nitrogen emissions into drainage water [26].

Perennial species are sources of lignocellulose in contrast to the starch substrates derived from conventional corn production for biofuel purposes. Biodiverse agroecosystems are therefore seen as a viable strategy to increase agroecosystem health and enhance resilience in the US Corn Belt.

4. The Importance of Underutilized Traditional Crops for Sustainable Food Production and Nutritional Security

In contrast to the above-mentioned major staple crops, underutilized, undervalued or neglected crops—also branded development opportunity crops (DOCs) [27]—are categorized in this article as "minor crops" that are already cultivated, but are underutilized regionally or globally given their still relatively low global production and market value [20,28,29]. Some of these crop species may be widely distributed globally, but are restricted to a more local production and consumption system. Many of these traditional crops grown for food, fiber, fodder, oil and as sources of traditional medicine play a major role in the subsistence of local communities and frequently are of special social, cultural and medicinal value. With good adaptation to often marginal lands, they constitute an important part of the local diet of communities providing valuable nutritional components, which are often lacking in staple crops [29].

As a result of the Green Revolution, many of those local, traditional crop species and varieties have been replaced by high-yielding staple crop cultivars developed by modern breeding programs. Traditional crops typically do not meet modern standards for uniformity and other characteristics as they have been neglected by breeders from the private and public sectors [20]. Thus they tend to be less competitive in the marketplace compared with commercial cultivars. Landraces and crop wild relatives have hitherto been increasingly valued and exploited for genes that provide increased biotic resistance, tolerance to abiotic stress, yield and quality [16,17,30]. However, use of agricultural biodiversity should not be restricted to exploiting valuable genes for use in breeding programs if our aim is to create more robust and resilient production systems. Currently underutilized food sources ranging from minor grains and pulses, root and tuber crops and fruits and vegetables to non-timber forest products have the potential to make a substantial contribution to food and nutrition security, to protect against internal and external market disruptions and climate uncertainties, and lead to better ecosystem functions and services, thus enhancing sustainability [31]. A wider use of neglected and undervalued crops and species, either intercropped with main staples in cereal-based systems or as stand-alone crops, would provide multiple options to build temporal and spatial heterogeneity into uniform cropping systems, thus enhancing resilience to biotic and abiotic stress factors and ultimately leading to a more sustainable supply of diverse and nutritious food.

Many traditional or indigenous vegetables are characterized by a high nutritional value compared with global vegetables like tomato and cabbage [32]. As source of essential vitamins, micronutrients, protein and other phytonutrients, traditional vegetables and underutilized legume crops such as mungbean have the potential to play a major role in strategies to attain nutritional security. Experiments with home gardens in India including about two dozen vegetable species have shown that a small area of 6 m × 6 m can provide much of the vitamin A and C requirement for a family of four during the entire year [32]. Apart from the provision of essential vitamins, many of the vegetable crops included in home garden kits are known to be naturally nutrient-dense [33,34]. Community-based seed conservation and multiplication has been used in the Philippines as an approach to enhance the adoption of nutrient-dense traditional vegetables and to generate additional farm income [35]. Given the high farmer acceptance, the continuation and expansion of this approach to the entire Bicol region has been proposed under the Regional High Value Commercial Crops (HVCC) Program of the Department of Agriculture to ensure the availability of high quality traditional vegetable seed for home garden and commercial production.

Apart from their commercial, medicinal and cultural value, traditional vegetables are also considered important for sustainable food production as they reduce the impact of production systems on the environment. Many of these crops are hardy, adapted to specific marginal soil and climatic conditions, and can be grown with minimal external inputs [36,37]. This is the case, for example, in the southern part of Rajasthan, India where due to the harsh climatic conditions only robust, drought-tolerant traditional vegetables with short growth cycles such as *Cucumis melo* var. *agrestis* (kachri) can survive and produce food [38].

5. Income Generation

Vegetables in general, but also many traditional vegetables such as amaranth (*Amaranthus* spp.), jute mallow (*Corchorus olitorius*), African nightshade (*Solanum scabrum*), Asian (*Solanum melongena*) and African (*Solanum aethiopicum*) eggplant, drumstick tree (*Moringa oleifera*), bitter gourd (*Momordica charantia*), water spinach (*Ipomoea aquatica*), Chinese kale (*Brassica oleracea* var. *alboglabra*), edible rape (*Brassica napus*), roselle (*Hibiscus sabdariffa*), Malabar spinach (*Basella alba*), slippery cabbage (*Abelmoschus manihot*), winged bean (*Psophocarpus tetragonolobus*) and many gourd species are of considerable commercial value and thus can make a significant contribution to household income. Hughes and Ebert [37] cite a number of examples of profitable cultivation of traditional vegetables in East and West Africa such as worowo (*Solanacio biafrae*), cockscomb (*Celosia argentea*), African eggplant (*Solanum macrocarpon*), and amaranth.

Value addition by applying appropriate production and postharvest techniques ensures that high quality produce reaches the market and satisfies consumer expectations. Consumer studies with regard to the purchase and consumption of kale (*B. oleracea*) in Nairobi, Kenya revealed that urban kale consumers care most for nutritional, sensory and safety attributes of the produce [39]. The highest estimates of willingness to pay more for the safety attribute of leafy vegetables were found in high-end specialty stores (68%), followed by open-air markets (39%), supermarkets (34%), and roadside markets (28%).

In Eastern Africa and Southeast Asia selected traditional vegetables are becoming an increasingly attractive food group for the wealthier segments of the population and are slowly moving out of the underutilized category into the commercial mainstream [40]. Attracted by the strong market demand, seed companies are beginning to explore and develop these popular crops, thus strengthening the formal seed sector [41].

6. Examples of Underutilized Vegetables and Legume Crops with Potential

Not all traditional and underutilized crops can simply and easily be turned into commercial success stories. Significant research, breeding and development efforts are needed to convert existing local landraces of carefully selected, promising crops into varieties with wide adaptation and commercial potential [20,28]. An overview of breeding efforts and application of biotechnology tools such as micropropagation, molecular marker studies and genetic transformation for the improvement of underutilized crops has recently been provided by Ochatt and Jain [28] and Jain and Gupta [29]. Access to genetic diversity of selected crops, either in situ or ex situ, is a pre-condition for success. Two underutilized traditional vegetable crops—amaranth and drumstick tree—and the underutilized legume crop mungbean are highlighted and briefly described. As indicated in section four, the term "underutilized" used here refers to as yet low global production and market value. All three crops have the potential to assume a more important role globally in the sustainable supply of diverse and nutritious food if given appropriate attention by plant breeders. The highlighted crops are well represented in AVRDC's genebank with substantial inter- and intra-specific genetic diversity [42], and all three crops already have demonstrated their potential for wider adoption and commercial exploitation.

6.1. Amaranth

Amaranth (*Amaranthus* spp.) is widely grown as a leafy vegetable and for grain production in many tropical countries in Africa, Central and South America, Mexico and parts of Asia. The genus *Amaranthus* consists of about 60 species, some of which have been cultivated for more than 5000 years [43]. The main grain species are *A. hypochondriachus* (Prince's feather), *A. cruentus* (purple amaranth), and *A. caudatus* (Inca wheat), all of which have their center of origin in Mesoamerica and South America [43,44]. The following species are well-known as leafy vegetables: *A. blitum* (livid or slender amaranth; origin: Mediterranean region in Central Europe), *A. dubius*, (spleen amaranth; origin: tropical America), and *A. tricolor*; origin: tropical Asia) [43–45]. Although originally known as cereal amaranth, *A. cruentus* is now the main vegetable amaranth in Africa, and to a lesser extent is also found in Asia [46].

Amaranth is ready for harvesting between 20 to 45 days after transplanting or sowing, depending on the variety and harvest season [44]. While low yields of leafy vegetables of less than 1.2 t/ha [47] are common in Africa, leafy amaranth has a yield potential of 32–40 t/ha and, therefore, is highly competitive [48]. Heavy rainfall in connection with typhoons often inflicts severe damage to leafy vegetables grown in typhoon-prone countries in East and Southeast Asia. To avoid or reduce such damage, production is moving into plastic houses in Taiwan during the summer months with temperatures inside often reaching up to 40 °C. Amaranth, cucurbits, and water spinach (*Ipomoea aquatica*) are some of the few crop choices under such extreme conditions [49,50]. Water spinach proved to be heat tolerant and amaranth moderately heat tolerant, while the majority of vegetable crops were either heat sensitive or only slightly heat tolerant as indicated by the membrane stability of vegetable leaves [50]. As a C4-cycle plant, amaranth can sustain high photosynthetic activity and water use efficiency under high temperatures and high radiation intensity, making it an ideal crop for abiotic stress conditions under changing climates [49].

Amaranth is a very nutritious leafy vegetable, both in raw and cooked form. The nutritional value of this crop is comparable to spinach, but much higher than cabbage and Chinese cabbage [44]. Amaranth is increasingly gaining importance both for household consumption and commercial production in Africa and Asia. There is a good market potential for this crop, both in the high-price and low-price segments. A small plot of amaranth of only 500 m^2 can earn a farmer in Tanzania a supplementary income of US$250 a year [37]. Amaranth has made its way from Tanzania into supermarkets in neighboring Nairobi, Kenya and the hotel catering business. Amaranth is often produced with relatively low inputs and thus has low capital risk for small-scale farmers. Commercial seed companies have recognized this market potential and are now including amaranth in their product portfolio. Given the inter- and intra-specific diversity of cultivated amaranth, this crop is an ideal choice for crop diversification, sustainable food production and nutrition security.

6.2. Drumstick Tree

The Moringaceae family comprises 13 species that fit into three broad life forms with distinct geographic origins [51]. Four species belong to the group of bottle trees with bloated water-storing trunks: *Moringa drouhardii* (Madagascar), *M. hildebrandtii* (Madagascar), *M. ovalifolia* (Namibia and southwest Angola), and *M. stenopetala* (Kenya and Ethiopia). Another three *Moringa* species are characterized by slender trees with a tuberous juvenile stage: *M. concanensis* (India), *M. oleifera* (India), and *M. peregrina* (Red Sea, Arabia, Horn of Africa). The remaining six tuberous Moringa species are found in northeast Africa: *M. arborea* (northeast Kenya), *M. borziana* (Kenya and Somalia), *M. longituba* (Kenya, Ethiopia, Somalia), *M. pygmaea* (northern Somalia), *M. rivae* (Kenya and Ethiopia), and *M. ruspoliana* (Kenya, Ethiopia, Somalia) [51].

M. oleifera is the predominant cultivated species of the Moringaceae family. It is widely grown in the tropics of Asia, Latin America, the Caribbean and sub-Saharan Africa, and can also be found in Florida and the Pacific Islands. It is a perennial softwood tree native to the sub-Himalayan ranges of India, Pakistan, Bangladesh and Afghanistan [52]. Moringa has already reached the status of an economically important crop in India, the Philippines, Ethiopia, and Sudan [52].

Food uses. Most parts of the tree are edible. The leaves and flowers are eaten as salad, as cooked vegetables, or added to soups and sauces or used to make tea [53,54]. The young, tender pods—known as drumsticks—are highly valued as a vegetable in Asia and also are pickled [55]. Fried seeds taste like groundnuts. The root bark has a pungent taste similar to horseradish (*Armoracia rusticana*) and is used as a condiment. Dried leaf powder is a good option to supplement diets of children and pregnant and lactating women [53]. For example, moringa leaf powder is added to a soybean and groundnut/peanut paste to form an energy-dense supplemental food known as ready-to-use food (RUF) for treatment of severe acute malnutrition [56].

Nutritional content. Moringa has a high nutrient density and is rich in many essential micronutrients and vitamins as well as antioxidants and bioavailable iron. It excelled among 120 species of Asian traditional vegetables tested for their content of micronutrients and phytochemicals, antioxidant activity (AOA), and traditional knowledge of their medicinal uses [57]. Moreover, it is easy to grow, has excellent processing properties, and good palatability [58]. Drying moringa leaves in a low temperature oven at 50 °C for 16 hours maintained most nutrients and phytochemicals, except vitamin C. Boiling fresh moringa leaves and dried powder in water enhanced aqueous AOA and increased bioavailable iron by 3.5 and 3 times, respectively [57].

Medicinal uses. The Moringa family is rich in glucosinolates and isothiocyanates [59,60]. Isothiocyanates are highly reactive compounds that inhibit mitosis and stimulate apoptosis, a physiological process eliminating DNA-damaged, unwanted cells in human tumor cells, and are therefore important to human health [61]. A recent analysis of the glucosinolate content of four moringa species maintained in the AVRDC field genebank revealed that *M. oleifera* had a 3-fold higher glucosinolate concentration than *M. stenopetala*, ranking second among the four species tested [62].

Dietary or topical administration of moringa in the form of extracts, decoctions, creams, oils, powders, and porridges have been reported in the scientific literature as having antibiotic, antitrypanosomal, hypotensive, antispasmodic, antiulcer, anti-inflammatory, hypo-cholesterolemic, and hypoglycemic activities [52]. Moringa powder has been recommended as an immune stimulant in HIV/AIDS treatment [63]. In folk medicine, moringa flowers, leaves, and roots are used for the treatment of various tumors, and seeds are specifically used to treat abdominal tumors [64]. A dramatic reduction in skin papillomas was observed following ingestion of moringa seedpod extracts [65].

Agronomic and horticultural uses. Moringa can be planted as a windbreak or living fence [66]. It has potential in alley cropping and as a component of agroforestry systems for sustainable vegetable production [67]. In some parts of Southeast Asia the tree is used as a support for climbers such as yams (*Dioscorea* spp.), beans (*Phaseolus* spp.), and black pepper (*Piper nigrum*). Moringa can be intercropped with a range of vegetables such as cluster bean (*Cyamopsis tetragonoloba*), hot pepper (*Capsicum* spp.), cowpea (*Vigna unguiculata*), and onion (*Allium cepa*). The leaves and twigs also serve as forage for livestock [54]. Moringa is grown as an ornamental tree in Latin America, the United States, and Africa [66].

Industrial uses. Moringa seed contains about 40% oil, known as ben oil. The oil is non-drying, resists rancidity, and is used for cooking, lubrication, and in the cosmetic industry [53]. The leftover pressed cake or ground moringa seeds are used to purify drinking water and to flocculate contaminants [52,54]. The wood can be used for dying (blue color) [53]. The coarse fiber of the trunk is suitable for making mats, cordage, and paper [68].

Among 75 traditional plant-derived oils tested in India for biofuel production, the oil derived from *M. oleifera* showed good potential [69]. The aptness of moringa oil for biofuel production was confirmed in a specific study using *M. oleifera* seeds from Pakistan [70]. Biodiesel obtained from moringa oil is characterized by a high cetane number of 67, one of the highest among biodiesel fuels.

Moringa is a fast-growing tree that adapts well to hot, semi-arid regions with as little as 500 mm annual rainfall [54]. It also tolerates occasional wet or waterlogged conditions for a short period of time [68], but prolonged flooding leads to a significant loss of plants [71]. In general, moringa grows best in lowland cultivation, but it also adapts to altitudes above 2000 m.

Greater use of moringa has good potential in the fight against hunger and malnutrition in the developing world by improving nutrition and health of the rural and urban poor, increasing incomes of smallholder farmers, and enhancing environmental services by controlling soil and wind erosion, and providing shade and clean water. Given its multiple uses and wide range of adaptability, moringa is an ideal crop for sustainable food production that would thrive as the climate changes.

6.3. Mungbean

The highest global production and consumption of pulses consisting mainly of chickpea, pigeonpea and mungbean is found in South and Southeast Asia. Mungbean, *Vigna radiata* var. *radiata*, is a relatively important legume crop in South and Southeast Asia, but is also known and grown in Africa and the Americas on a still relatively small scale. The annual mungbean production currently reaches more than six million hectares worldwide. This is already a significant level of production for an underutilized crop, however, insignificant when compared with the area covered by the major cereal crops. Half of the worldwide mungbean production is generated in India (3 million hectares), followed by China and Myanmar [72]. Mungbean is a good source of dietary protein with high contents of folate and iron compared with many other legume crops [73]. As it is a short duration legume, it fits well into the fallow period between rice-rice, rice-wheat, rice-potato-wheat, maize-wheat, cotton, and other cash crop cropping systems in use across the Indo-Gangetic plain. Planting mungbean improves soil properties and provides additional nitrogen to subsequent crops. The yield of rice following a mungbean intercrop can increase by up to 8% through the nitrogen fixed by mungbean in the soil and due to reduced pest and disease pressure [74].

The genus *Vigna* subgenus *Ceratotropis* consists of 17 recognized species that are naturally distributed across Asia and are, therefore, also referred to as Asian *Vigna* [75]. Among those 17 species, eight species are considered as cultivated or semi-domesticated (the number of respective accessions held in the AVRDC genebank are given in parenthesis): *V. radiata* (mungbean; 6737); *Vigna mungo* (black gram; 853); *V. angularis* (azuki bean; 2376 accessions); *V. umbellata* (rice bean; 369 accessions); *V. aconitifolia* (moth bean; 22 accessions); *V. trilobata* (pillipsesara bean; 2 accessions); *V. stipulacea; V. glabrescens* (Lentille de créole; 3); and *V. trinervia* [42,75]. Other wild *Vigna* species held in AVRDC's collection are: *V. caracalla* (1); *V. luteola* (2); *V. marina* (3); *V. parkeri* (1); *V.* spp. (189 accessions with unidentified species); and *V. vexillata* (2).

In the 1980s the International Board for Plant Genetic Resources (IBPGR) designated AVRDC as the international research and development center with responsibility for the maintenance of the global base collection of mungbean. The AVRDC collection currently consists of 6737 well-characterized accessions [42]. The AVGRIS characterization database contains detailed descriptions of 9198 accessions and sub-accessions, an indication that in this crop many sub-accessions have been created due to clear variations of mainly seed characteristics in the original accessions.

The majority of the mungbean accessions have been evaluated for morphological and agronomic characteristics, nutritional composition, and resistance or tolerance to major pests and diseases under replicated yield trials. Significant genetic divergence was found when comparing AVRDC mungbean lines with varieties grown in India, offering a sound basis for further varietal improvement [76].

Thirty years ago, mungbean was still a semi-domesticated crop cultivated on marginal land with minimal external inputs. Early cultivars were indeterminate requiring multiple harvest cycles and reached maturity in 90–110 days [77]. They were highly susceptible to diseases and insect pests, had problems with pod shattering, and yielded only about 400 kg/ha of small seed. AVRDC played a significant role in the full domestication of the crop and in the development of short-duration mungbean lines in Asia with a maturity period of 55–65 days, thus easily fitting into cereal-dominated cropping systems [78]. Major breeding objectives of the early mungbean improvement program at AVRDC were lines with stable, high yield, determinate growth habit, early and uniform maturity, bold seeds, less sensitivity to photoperiod and temperature and resistance to diseases and insect pests. Germplasm sources from the Philippines and India were instrumental in the development of improved varieties for Southeast Asia. The gene pool from India contributed resistance to Cercospora leaf spot and powdery mildew while the accessions from the Philippines provided traits for high yield, uniform maturity, earliness and bold seed [77].

Further improvement was done by incorporating resistance to *Mungbean yellow mosaic virus* (MYMV) from resistant lines developed in Pakistan. New improved mungbean varieties with resistance or tolerance to MYMV, early and uniform maturity, and large-size seed have been subsequently released to farmers in South Asia. The introduction of these new lines to National Agricultural Research and Extension Systems (NARES) was achieved through the AVRDC International Mungbean Nursery, which supplied promising lines annually for local screening and evaluation. The yield potential of AVRDC-derived mungbean cultivars has doubled, pod maturity at first harvest has increased to 80%, plants are less sensitive to photoperiod, and resistance to pests and diseases has increased. These agronomic qualities favored the wide adoption of the new cultivars. Recent variety releases in South Asia are listed in a publication by Chadha [78].

Mungbean production in Asia increased by 35% from 2.3 million t in 1985 to 3.1 million t in 2000 due to the introduction of improved AVRDC-derived lines [74]. Close to 1.5 million farmers in Asia adopted improved mungbean varieties on 50 to 95% of total mungbean area between 1984 and 2006, realizing a yield increase of 28%–55% [77]. During the same period consumption of mungbean increased 22%–66%, benefitting 1.5 million anemic children and leading to an estimated economic benefit due to the improved health of anemic women of US$3.5 million to US$4 million per country [77].

With an average yield of about 400 kg/ha, the productivity of mungbean is still relatively low, although it is similar to other pulse crops. Broadening the genetic base by selecting parents from diverse cultivated and interspecific backgrounds is of great importance to achieve productivity gains [72]. Other major breeding goals are resistance to mungbean yellow mosaic disease and bruchid as well as improvement of protein quality by selecting high methionine lines. AVRDC's diverse mungbean collection is the ideal storehouse for selection of accessions which might help achieve these new major breeding goals. Draft whole genome sequences for mungbean and some wild relatives will become available at AVRDC at the beginning of 2014, and this will strengthen genomics research and enhance molecular and conventional breeding of this crop. Realizing the narrow genetic base of current commercial mungbean cultivars in Australia, the Australian mungbean program has recently begun evaluating and screening hundreds of AVRDC accessions for inclusion in their future national breeding program. Once low yield and disease and insect pest problems of mungbean have been successfully addressed by plant breeders, there is great potential for this crop to play a more significant global role as an important source of vegetable protein.

The intensive regional collaboration between AVRDC and national partners in recent years has already led to the release of 125 improved mungbean varieties based on AVRDC breeding lines and genebank accessions in 29 countries worldwide from 1978 to 2013. The top ten countries that released the highest number of lines from AVRDC-developed mungbean materials were China (21); Vietnam (12); Bangladesh (8); Thailand (8), Australia (7); Korea (7); India (6); Indonesia (6); Philippines (6); and Pakistan (6). Worldwide, improved AVRDC-derived mungbean lines constitute now more than 25% of mungbean production [79].

7. Conclusions

As can be concluded from the examples of the three minor crops described in this article, and in particular from the mungbean example, there is great potential for a number of currently underutilized crops to play a major role in a more diversified and sustainable food production system. However, there must be greater investment in long-term research and breeding programs and improved seed supply sources for these crops to ensure they can be competitive in the marketplace. Research and breeding of underutilized fruit and vegetable crops are clearly underfunded compared with the few main staple crops. Substantial initial funding by the international donor community and national state programs is necessary to achieve this goal and to generate interest among private sector breeders once significant market potential is within reach.

Acknowledgments

The critical review of a prior version of this manuscript by J.D.H. Keatinge is gratefully acknowledged.

Conflicts of Interest

The author declares no conflict of interest.

References

1. Godfray, H.C.J.; Beddington, J.R.; Crute, I.R.; Haddad, L.; Lawrence, D.; Muir, J.F.; Pretty, J.; Robinson, S.; Thomas, S.M.; Toulmin, C. Food security: The challenge of feeding 9 billion people. *Science* **2010**, *327*, 812–818.
2. Bruinsma, J. The Resource Outlook to 2050: By How Much do Land, Water and Crop Yields Need to Increase by 2050? In *Proceedings of the Technical Meeting of Experts on How to Feed the World in 2050, Rome, Italy, 24–26 June 2009*; Food and Agriculture Organization (FAO): Rome, Italy, 2009; pp. 1–33.
3. Tilman, D.; Balzer, C.; Hill, J.; Befort, B.L. Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 20260–20264.
4. Keyzer, M.A.; Merbis, M.D.; Pavel, I.F.P.W.; van Wesenbeeck, C.F.A. Diet shifts towards meat and the effects on cereal use: Can we feed the animals in 2030? *Ecol. Econ.* **2005**, *55*, 187–202.
5. FAOSTAT. Available online: http://faostat3.fao.org/home/index.html#DOWNLOAD (accessed on 21 November 2013).
6. Smil, V. Nitrogen and food production: Proteins for human diets. *Ambio* **2002**, *31*, 126–131.
7. Pimentel, D.; Marklein, A.; Toth, M.A.; Karpoff, M.N.; Paul, G.S.; McCormack, R.; Kyriazis, J.; Krueger, T. Food versus biofuels: Environmental and economic costs. *Hum. Ecol.* **2009**, *37*, 1–12.
8. Tilman, D.; Fargione, J.; Wolff, B.; D'Antonio, C.; Dobson, A.; Howarth, R.; Schindler, D.; Schlesinger, W.H.; Simberloff, D.; Swackhamer, D. Forecasting agriculturally driven global environmental change. *Science* **2001**, *292*, 281–284.
9. Fischer, R.A.; Edmeades, G.O. Breeding and cereal yield progress. *Crop Sci.* **2010**, *50*, S-85–S-98.
10. Day, W.; Audsley, E.; Frost, A.R. An engineering approach to modeling, decision support and control for sustainable systems. *Philos. Trans. R. Soc. B* **2008**, 363, 527–541.

11. Stern, N. The economics of climate change. *Am. Econ. Rev.* **2008**, *98*, 1–37.
12. Corvalan, C.; Hales, S.; McMichael, A. *Ecosystems and Human Well-Being: Health Synthesis*; A Report of the Millennium Ecosystem Assessment; World Health Organization: Geneva, Switzerland, 2005.
13. United Nations Environment Programme (UNEP). *Keeping Track of our Changing Environment: From Rio to Rio+20 (1992–2012)*; Division of Early Warning and Assessment (DEWA); UNEP: Nariobi, Kenya, 2011; p. 99.
14. World Wildlife Fund (WWF). *Living Planet Report 2010: Biodiversity, Biocapacity and Development*; WWF: Gland, Switzerland, 2010; p. 55.
15. Carrière, S.M.; Rodary, E.; Méral, P.; Serpantié, G.; Boisvert, V.; Kuli, C.A.; Lestrelin, G.; Lhoutellier, L.; Moizo, B.; Smektala, G.; *et al*. Rio+20, biodiversity marginalized. *Conserv. Lett.* **2013**, *6*, 6–11.
16. Frison, E.A.; Cherfas, J.; Hodgkin, T. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability* **2011**, *3*, 238–253.
17. Jackson, L.E.; Pascual, U.; Hodgkin, T. Utilizing and conserving agrobiodiversity in agricultural landscapes. *Agric. Ecosyst. Environ*. **2007**, *121*, 196–210.
18. Juma, C.; Tabo, R.; Wilson, K.; Conway, G. *Innovation for Sustainable Intensification in Africa*; The Montpellier Panel, Agriculture for Impact: London, UK, 2013. Available online: https://workspace.imperial.ac.uk/africanagriculturaldevelopment/Public/MP_0047_Report_V5_Low-res_singlepages.pdf (accessed on 21 November 2013).
19. The Montpellier Panel. *Sustainable Intensification: A New Paradigm for African Agriculture*; The Montpellier Panel: London, UK, 2013.
20. Stamp, P.; Messmer, R.; Walter, A. Competitive underutilized crops will depend on the state funding of breeding programmes: An opinion on the example of Europe. *Plant Breed.* **2012**, *131*, 461–464.
21. IRRI. The Importance of Rice. Available online: http://www.knowledgebank.irri.org/ericeproduction/Importance_of_Rice.htm (accessed on 21 November 2013).
22. Keatinge, J.D.H.; Ledesma, D.R.; Keatinge, F.J.D.; Hughes, J.d'A. Projecting annual air temperature changes to 2025 and beyond: Implications for vegetable horticulture worldwide. *J. Agric. Sci*. **2012**, doi:10.1017/S0021859612000913.
23. Newton, A.C.; Johnson, S.N.; Gregory, P.J. Implications of climate change for diseases, crop yields and food security. *Euphytica* **2011**, *179*, 3–18.
24. Lin, B.B. Resilience in agriculture through crop diversification: Adaptive management for environmental change. *BioScience* **2011**, *61*, 183–193.
25. Bobojonov, I.; Lamers, J.P.A.; Bekchanov, M.; Djanibekov, N.; Franz-Vasdeki, J.; Ruzimov, J.; Martius, C. Options and constraints for crop diversification: A case study in sustainable agriculture in Uzbekistan. *Agroecol. Sustain. Food Syst.* **2013**, *37*, 788–811.
26. Liebman, M.Z.; Helmers, M.J.; Schulte, L.A.; Chase, C.A. Using biodiversity to link agricultural productivity with environmental quality: Results from three field experiments in Iowa. *Renew. Agric. Food Syst.* **2013**, *28*, 115–128.

27. Kahane, R.; Hodgkin, T.; Jaenicke, H.; Hoogendoorn, C.; Hermann, M.; Keatinge, J.D.H.; Hughes, J.d'A.; Padulosi, S.; Looney, N. Agrobiodiversity for food security, health and income. *Agron. Sustain. Dev.* **2013**, *33*, 671–693.
28. Ochatt, S.; Jain, S.M. *Breeding of Neglected and Under-Utilized Crops, Spices and Herbs*; Science Publishers Inc.: Enfield, NH, USA, 2007.
29. Jain, S.M., Gupta, S.D., Eds. *Biotechnology of Neglected and Underutilized Crops*; Springer: Berlin, Germany, 2013.
30. McCouch, S. Feeding the future. *Nature* **2013**, *499*, 23–24.
31. Keatinge, J.D.H.; Waliyar, F.; Jamnadass, R.H.; Moustafa, A.; Andrade, M.; Drechsel, P.; Hughes, J.d'A.; Palchamy, K.; Luther, K. Re-learning old lessons for the future of food—by bread alone no longer: Diversifying diets with fruit and vegetables. *Crop Sci.* **2010**, *50*, 51–62.
32. Keatinge, J.D.H.; Yang, R.-Y.; Hughes, J.d'A.; Easdown, W.J.; Holmer, R. The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals. *Food Sci*. **2011**, *3*, 491–501.
33. Hughes, J.d'A.; Keatinge, J.D.H. The Nourished Millennium: How Vegetables Put Global Goals for Healthy, Balanced Diets within Reach. In *High Value Vegetables in Southeast Asia: Production, Supply and Demand*; Proceedings of the SEAVEG 2012 Regional Symposium; Holmer, R., Linwattana, G., Nath, P., Keatinge, J.D.H., Eds.; AVRDC - The World Vegetable Center: Tainan, Taiwan, 2013; pp. 11–26.
34. Yang, R.-Y.; Keding, G.B. Nutritional Contributions of Important African Indigenous Vegetables. In *African Indigenous Vegetables in Urban Agriculture*; Shackleton, C.M., Pasquini, M., Drescher, A.W., Eds.; Earthscan: London, UK, 2009; pp. 105–143.
35. Ebert, A.W.; Hidayat, I.M.; de los Santos, E.B. Cultivar Trials of Indigenous Vegetables in Indonesia and Community-Based Seed Conservation and Multiplication in the Philippines. In *Proceedings of the 2nd International Symposium on Underutilized Plant Species: Crops for the Future—Beyond Food Security*; Massawe, F., Mayes, S., Alderson, P., Eds.; International Society for Horticultural Sciences (ISHS): Korbeek-Lo, Belgium, 2013; Volume 2, pp. 341–348.
36. De la Peña, R.C.; Ebert, A.W.; Gniffke, P.; Hanson, P.; Symonds, R.C. Genetic Adjustment to Changing Climates: Vegetables. In *Crop Adaptation to Climate Change*, 1st ed.; Yadav, S.S., Redden, R.J., Hatfield, J.L., Lotze-Campen, H., Hall, A.E., Eds.; John Wiley & Sons, Ltd.: Chichester, UK, 2011; pp. 396–410.
37. Hughes, J.d'A.; Ebert, A.W. Research and Development of Underutilized Plant Species: The Role of Vegetables in Assuring Food and Nutritional Security. In *Proceedings of the 2nd International Symposium on Underutilized Plant Species: Crops for the Future—Beyond Food Security*; Massawe, F., Mayes, S., Alderson, P., Eds.; International Society for Horticultural Sciences (ISHS): Korbeek-Lo, Belgium, 2013; Volume 2, pp. 79–91.
38. Maurya, I.B.; Arvindakshan, K.; Sharma, S.K.; Jalwania, R. Status of Indigenous Vegetables in Southern Part of Rajasthan. In *Proceedings of the 1st International Conference on Indigenous Vegetables and Legumes—Prospectus for Fighting Poverty, Hunger and Malnutrition*; Chadha, M.I., Kuo, G., Gowda, C.L.L., Eds.; International Society for Horticultural Sciences (ISHS): Korbeek-Lo, Belgium, 2007; pp. 193–196.

39. Ngigi, M.W.; Okello, J.J.; Lagerkvist, C.L.; Karanja, N.K.; Mburu, J. Urban consumers' willingness to pay for quality of leafy vegetables along the value chain: The case of Nairobi Kale consumers, Kenya. *Int. J. Bus. Soc. Sci.* **2011**, *2*, 209–216.
40. Weinberger, K. Are indigenous vegetables underutilized crops? Some evidence from Eastern Africa and Southeast Asia. *Acta Hortic*. **2007**, *752*, 29–34.
41. AVRDC - The World Vegetable Center. *Point of Impact: Healthy Urban Fast Food: A New Maasai Enterprise*; AVRDC - The World Vegetable Center: Tainan, Taiwan, 2008.
42. AVGRIS—AVRDC Vegetable Genetic Resources Information System. Available online: http://203.64.245.173/ (accessed on 21 November 2013).
43. Dehmer, K.J. Molecular Diversity in the Genus *Amaranthus*. In *Rudolf Mansfeld and Plant Genetic Resources, Schriften zu Genetischen Ressourcen. Zentralstelle für Agrardokumentation und–Information (ZADI)*; Knüpffer, H., Ochsmann, J., Eds.; Zentralstelle für Agrardokumentation und -Information (ZADI): Bonn, Germany, 2003; pp. 208–215.
44. Ebert, A.W.; Wu, T.-H.; Wang, S.-T. *International Cooperators' Guide—Vegetable Amaranth (Amaranthus L.)*; AVRDC - The World Vegetable Center: Tainan, Taiwan, 2011; p. 8.
45. Grubben, G.J.H., Denton, O.A., Eds. *Plant Resources of Tropical Africa, Volume 2: Vegetables*; Backhuys Publishers: Kerkwerve, The Netherlands, 2004; pp. 84–89.
46. Grubben, G.J.H. *Amaranthus* L. In *Plant Resources of South-East Asia. No. 8. Vegetables*; Siemonsma, J.S., Piluek, K., Eds.; Prosea Foundation: Bogor, Indonesia, 1994; pp. 82–86.
47. Mabulu, R.B.; Chalamila, B.N. Organic vegetable production an alternative income generating activity to the disease effected coconut farming system in Mkuranga District in Tanzania. *Afr. Crop Sci. Conf. Proc.* **2005**, *7*, 1539–1544.
48. Oluoch, M.O.; Pichop, G.N.; Silué, D.; Abukutsa-Onyango, M.O.; Diouf, M.; Shackleton, C.M. Production and Harvesting Systems for African Indigenous Vegetables. In *African Indigenous Vegetables in Urban Agriculture*; Shackleton, C.M., Pasquini, M.W., Drescher, A.W., Eds.; Earthscan: London, UK, 2009; pp. 145–176.
49. Wang, S.T.; Ebert, A.W. Breeding of Leafy Amaranth for Adaptation to Climate Change. In *High Value Vegetables in Southeast Asia: Production, Supply and Demand*; Proceedings of the SEAVEG 2012 Regional Symposium; Holmer, R., Linwattana, G., Nath, P., Keatinge, J.D.H., Eds.; AVRDC - The World Vegetable Center: Tainan, Taiwan, 2013; pp. 36–43.
50. Kuo, C.G.; Chen, H.M.; Sun, H.C. Membrane Thermostability and Heat Tolerance of Vegetable Leaves. In *Adaptation of Food Crops to Temperature and Water Stress*; AVRDC - The World Vegetable Center: Tainan, Taiwan, 1992; pp. 160–168.
51. Olson, M. The Home Page of the Plant Family Moringaceae. Available online: http://www.mobot.org/gradstudents/olson/moringahome.html (accessed on 21 November 2013).
52. Fahey, J.W. *Moringa oleifera*: A review of the medical evidence for its nutritional, therapeutic, and prophylactic properties. Part 1. *Phytochemistry* **2005**, *47*, 123–157.
53. Duke, J.A. *Moringa Oleifera* Lam. Available online: http://www.hort.purdue.edu/newcrop/duke_energy/Moringa_oleifera.html (accessed on 21 November 2013).
54. Bosch, C.H. *Moringa Oleifera* Lam. In *Plant Resources of Tropical Africa, Volume 2: Vegetables*; Grubben, G.J.H., Denton, O.A., Eds.; Backhuys Publishers: Kerkwerve, The Netherlands, 2004; pp. 392–395.

55. Ramachandran, C.; Peter, K.V.; Gopalakrishnan, P.K. Drumstick (*Moringa oleifera*): A multipurpose Indian vegetable. *Econ. Bot*. **1980**, *34*, 276–283.
56. Jilcott, S.B.; Ickes, S.B.; Ammerman, A.S.; Myhre, J.A. Iterative design, implementation and evaluation of a supplemental feeding program for underweight children ages 6–59 months in Western Uganda. *Matern. Child Health J*. **2010**, *14*, 299–306.
57. Yang, R.-Y.; Chang, L.-C.; Hsu, J.-C.; Weng, B.B.C.; Palada, M.C.; Chadha, M.L.; Levasseur, V. Nutritional and Functional Properties of Moringa Leaves—From Germplasm, to Plant, to Food, to Health. In Proceedings of the Moringa and other Highly Nutritious Plant Resources: Strategies, Standards and Markets for a Better Impact on Nutrition in Africa, Accra, Ghana, 16–18 November 2006; pp. 1–8.
58. Yang, R.-Y.; Tsou, S.C.S.; Lee, T.-C.; Chang, L.-C.; Kuo, G.; Lai, P.-Y. Moringa, a Novel Plant Rich in Antioxidants, Bioavailable Iron, and Nutrients. In *Herbs: Challenges in Chemistry and Biology*; ACS Symposium Series; American Chemical Society: Washington, DC, USA, 2006; Volume 925, pp. 224–239.
59. Fahey, J.W.; Zalcmann, A.T.; Talalay, P. The chemical diversity and distribution of glucosinolates and isothiocyanates among plants. *Phytochemistry* **2001**, *56*, 5–51.
60. Bennett, R.N.; Mellon, F.A.; Foidl, N.; Pratt, J.H.; Dupont, M.S.; Perkins, L.; Kroon, P.A. Profiling glucosinulates and phenolics in vegetative and reproductive tissues of the multi-purpose trees *Moringa oleifera* L. (horseradish tree) and *Moringa stenopetala* L. *J. Agric. Food Chem*. **2003**, *51*, 3546–3553.
61. Johnson, T. Glucosinulates: Bioavailability and importance to health. *Int. J. Vitam. Nutr. Res*. **2002**, *72*, 26–31.
62. Ulrichs, C. First results of the glucosinolate analysis of *Moringa* spp. Humboldt-Universität zu Berlin, Berlin, Germany. Personal communication, February 2010.
63. Burger, D.J.; Fuglie, L.; Herzig, J.W. The Possible Role of *Moringa Oleifera* in HIV/AIDS Supportive Treatment. In Proceedings of the 14th International Conference on AIDS, Barcelona, Spain, 7–12 July 2002; pp. 7–12.
64. Hartwell, J.L. Plants used against cancer. A survey. *Lloydia* **1969**, *32*, 78–107.
65. Bharali, R.; Tabassum, J.; Azad, M.R.H. Chemomodulatory effect of *Moringa oleifera*, Lam. on hepatic carcinogen metabolizing enzymes, antioxidant parameters and skin papillomagenesis in mice. *Asian Pac. J. Cancer Prev.* **2003**, *4*, 131–139.
66. Jahn, S.A.A.; Musnad, H.A.; Burgstaller, H. The tree that purifies water: Cultivating multipurpose Moringaceae in the Sudan. *Unasylva* **1986**, *38*, 23–28.
67. Palada, M.C. Moringa (*Moringa oleifera* Lam.): A versatile tree crop with horticultural potential in the subtropical United States. *HortScience* **1996**, *31*, 794–797.
68. Polprasid, P. *Moringa oleifera* Lamk. In *PROSEA—Plant Resources of South-East Asia No. 8: Vegetables*; Siemonsma, J.S., Piluek, K., Eds.; Prosea Foundation: Bogor, Indonesia, 1996; pp. 213–215.
69. Azam, M.M.; Waris, A.; Nahar, N.M. Properties and potential of fatty acid methyl esters of some non-traditional seed oils for use as biodiesel in India. *Biomass Bioenerg.* **2005**, *29*, 293–302.
70. Rashid, U.; Anwar, F.; Moser, B.R.; Knothe, G. *Moringa oleifera* oil: A possible source of biodiesel. *Bioresour. Technol.* **2008**, *99*, 8175–8179.

71. Patricio, H.G.; Palada, M.C.; Ebert, A.W. Adaptability and Horticultural Characterization of Moringa Accessions under Central Philippines Conditions. In *High Value Vegetables in Southeast Asia: Production, Supply and Demand*; Proceedings of the SEAVEG 2012 Regional Symposium; Holmer, R., Linwattana, G., Nath, P., Keatinge, J.D.H., Eds.; AVRDC - The World Vegetable Center: Shanhua, Tainan, Taiwan, 2013; pp. 61–70.
72. Nair, R.M.; Schafleitner, R.; Kenyon, L.; Srinivasan R.; Easdown, W.; Ebert, A.W.; Hanson, P. Genetic improvement of mungbean. *SABRAO J. Breed. Genet.* **2012**, *44*, 177–190.
73. Keatinge, J.D.H.; Easdown, W.; Yang, R.-Y.; Chadha, M.; Shanmugasundaram, S. Overcoming chronic malnutrition in a future warming world: The key importance of mungbean and vegetable soybean. *Euphytica* **2011**, *180*, 129–141.
74. Weinberger, K. *Impact Analysis of Mungbean Research in South and Southeast Asia*; AVRDC - The World Vegetable Center: Tainan, Taiwan, 2003.
75. Tomooka, N.; Egawa, Y.; Kaga, A. Biosystematics and Genetic Resources of the Genus *Vigna* Subgenus *Ceratotropis*. In *The Seventh Ministry Of Agriculture, Forestry And Fisheries (MAFF), Japan, International Workshop On Genetic Resources, Ibaraki, Japan, 13–15 October 1999: Part 1, Wild Legumes*; Research Council Secretariat of MAFF and National Institute of Agrobiological Resources: Tsukuba, Japan, 2000; pp. 37–62.
76. Prakash, V.; Siag, R.K.; Bains, T.S. Genetic Divergence in Indigenous and Exotic Genotypes of Mungbean. In *Proceedings of the First International Conference on Indigenous Vegetables and Legumes—Prospectus for Fighting Poverty, Hunger and Malnutrition*; ISHS Acta Horticulturae 752; Chadha, M.L., Kuo, G., Gowda, C.L.L., Eds.; International Society for Horticultural Science (ISHS): Korbeek-Lo, Belgium, 2007; pp. 165–168.
77. Shanmugasundaram, S.; Keatinge, J.D.H.; Hughes, J.d'A. The Mungbean Transformation: Diversifying Crops, Defeating Malnutrition. In *Proven Successes in Agricultural Development: A Technical Compendium to Millions Fed*; IFPRI Discussion Paper 00922; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2009.
78. Chadha, M.L. *Short Duration Mungbean: A New Success in South Asia*; Asia-Pacific Association of Agricultural Research Institutions (APAARI): Bangkok, Thailand, 2010.
79. Shanmugasundaram, S. New breakthrough with mungbean. *Centerpoint* **2001**, *19*, 1–2.