Research and development of underutilized plant species: The role of vegetables in assuring food and nutritional security

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Abstract
Climate change and population growth in many developing countries impede progress toward achieving food and nutritional security. Production of an expanded range of food crops can reduce risk and enhance food security. Diversified diets, based on a range of crop species, are essential for nutritional security. Vegetables are an excellent source of vitamins and micronutrients; increasing vegetable consumption can help alleviate malnutrition from imbalanced diets wherever it occurs, in developing countries as well as in developed countries. Vegetables are high value cash crops that generate employment and income, and contribute to gender equity and better livelihoods. Many vegetables - indigenous vegetables in particular - have high levels of micronutrients and could significantly contribute to nutritional security if eaten as part of the daily diet. Many indigenous vegetables adapt easily to degraded soils and to drought-prone, flooded, or saline land, and can be more resilient to extreme climatic events. Despite the importance of indigenous vegetables in combating malnutrition and poverty, and despite the wealth of traditional knowledge about these species, many are still poorly studied and understood by the scientific community. AVRDC – The World Vegetable Center conserves a highly diverse collection of indigenous vegetables, and is engaged in multiplying selected lines of a wide range of crops while conserving their genetic resource base. These indigenous vegetables (e.g. African nightshade, Asian and African eggplant, drumstick tree, bitter gourd, water spinach, amaranth, Chinese kale, edible rape, roselle, Malabar spinach, slippery cabbage, winged bean, and many gourd species) are assessed for agronomic, production, postharvest and nutritional characteristics. The best species and lines are promoted, production guidelines are prepared, and food preparation and nutritional guidance is made available to ensure they are adopted and contribute to food and nutritional security.

INTRODUCTION
Presently, 13.6% of the estimated world population of 6.8 billion is undernourished (FAO, 2010). Despite the fact that the world produces sufficient food to feed its population, 925 million people do not have access to adequate food because of poverty, faulty economic systems, civil unrest or military conflict. The undernourished in this context are usually associated with insufficient food intake, which is generally poverty-related hunger. However, the number of the world’s population suffering from malnourishment caused by a lack of nutritional microelements necessary for human health is believed to be much higher. In 2006 experts estimated that 2 billion people suffer from micronutrient malnourishment, mainly from insufficient intake of vitamin A, zinc and iron (WHO and FAO, 2006). This ‘hidden hunger’ can be silently manifested
among both the poor and the more affluent of the world’s population. For the poor, hidden hunger is mostly due to insufficient consumption of food items other than staples as household resources are unable to afford food for balanced diets and other household needs such as medical care and education for the children; more affluent populations, on the other hand, often over-consume fats, carbohydrates and protein. With the world population moving toward 7 billion, many developing countries where nearly all of the undernourished and many of the malnourished live, are struggling to make progress toward food and nutritional security.

GLOBAL CHALLENGES FOR FOOD AND NUTRITIONAL SECURITY

Populations

In addition to the ever-increasing world population, there are national demographic changes that affect the ability of countries to feed and sustain their own population. While many of the rural poor migrate to the cities in the hope of finding employment, this leaves an aging rural population that tries to feed not only itself, but also support increasingly densely populated cities.

In Asia and Africa, the rate of urbanization of 40% and 38% respectively in 2005 is expected to keep growing in the next 25 years (UNFPA, 2007). The primary reason for urbanization in Africa is the movement of people uprooted from rural areas by drought, famine, civil or ethnic conflict, and war. In China, the 2010 national census showed that the increased rate of urbanization resulted in half of the population now living in the cities. This urbanization drove 81% more farmers than in 2000 to cities (Caijing, 2011). In Europe, aging farmers present a significant challenge for food security, as at least 4.5 million farmers will retire from agricultural industries in the next 10 years while few young people will replace them (European Parliament, 2011).

Climate uncertainty

Global climate uncertainty adds to the burden of attaining global food and nutritional security as erratic climatic events threaten the production of food crops and can destroy agricultural production in entire regions.

In recent times, severe weather events caused by climate change have disrupted agricultural production in many areas in the world. Russia’s worst drought in over a century devastated the country’s 2010 harvest and cut grain production by almost 40% (Hernandez et al., 2010). Recent flooding following a previous drought period in Australia has significantly affected vegetable production in southeastern Queensland and decreased production of wheat in New South Wales by 15% (Australian Bureau of Statistics, 2011).

Climate shifts and changes around the globe create new ecological niches which enable establishment of insect pests and diseases into new areas and change their distribution pattern from one region to another. This results in higher pest and disease incidence in agricultural production systems. For example, the increasing global temperature is expanding the environment suitable for fruit flies (Bactrocera dorsalis), which might lead to increased damage to fruit and vegetable production (FAO, 2008). In conjunction with higher incidence of pest and diseases, the use of chemicals and
pesticides in agricultural production systems will also increase, leading to higher, unsafe levels of residues in the produce.

**Soil, water, and the environment**

Intensification of food production can have a significant negative impact on soil, water and the environment. Crop production, in most cases, depletes soil nutrients and intensive production systems tend to destroy soil structure. This can lead to an over-reliance on inorganic fertilizers to achieve acceptable yields, yet the fertilizers may be neither affordable nor available for many poor farmers. On the other hand, unwise and excessive use of fertilizers may contribute to declining soil quality. Overuse of fertilizers in vegetable cropping systems in the North China Plain resulted in soil with a lower pH and higher electrical conductivity and cadmium concentration compared with the wheat-maize cropping system (Ju *et al*., 2007). This condition was caused by excessive accumulation of salt and nitrate from fertilizers, causing rapid soil deterioration.

With poor soil quality there is a tendency to apply high levels of fertilizers wherever affordable. Rain and run-off water may leach the nutrients into the groundwater, contaminating water reservoirs for human and animal consumption and thus compromising human and animal health. With major environmental changes there are concomitant build-ups of insect pests and diseases, which farmers often tackle through the injudicious use of pesticides. These again can find their way into the groundwater, contaminating water sources used for domestic, agricultural and industrial activities. A study conducted in Izmir District, Aegean Region of Turkey showed that nitrate concentration in groundwater increased during the months of major agricultural activities and the concentration of the pesticides propargit, endosulfan and fenitrothion exceeded the maximum level allowed for pesticides in the local drinking water supply (Ovez *et al*., 2005).

Lack of water is becoming an increasingly important constraint to production, either because of economic scarcity—where an adequate amount of water is available but the population lacks the financial means and/or necessary infrastructure to access it—or physical water scarcity, where there simply is not enough water. Soil salinity is linked to water scarcity: a build-up of salt compromises soil quality and reduces the capability of arable land to be used for crop cultivation. Under-irrigation caused by lack of water provides adequate water for the plant, but not enough to leach the soluble salt deeper under the plant’s roots, resulting in increased soil salinity. Salinity build-up perpetuates the lack of available water for the crops as it prevents the plant from accessing water in the soil. Elemental ions such as sodium, calcium, chlorine and magnesium play a significant role in increasing toxicity levels in soils plagued by salinity.

With increasing intensification of production, care needs to be taken to ensure there is sufficient water of suitable quality for crop production, and production technologies need to be designed to ensure they do not adversely affect the environment, e.g. by creating environments in which malarial mosquitoes can breed. Without proper caution, the irrigation of agroecosystems can spread malaria; more importantly, pesticide contamination in the irrigation water may lead to increased resistance of mosquitoes against control agents such as pesticides and many drugs. As agricultural intensification requires expansion of irrigated areas, it is vital to apply sound water management in
agroecosystems to avoid increasing incidence of malaria (WHO, 2005) and other vector-borne diseases such as Japanese encephalitis and filariasis.

Markets
Markets are a critical aspect of production—without markets, produce cannot be sold and cannot reach the consumer. Markets are affected by poverty, by policy, and by people. Locally, markets are influenced by culture as well as crops. Policies affect how markets function and the economics of local, national, regional, and global markets determine how much of the produce is profitable and how much of the profit is returned to the farmer.

Civil unrest, the internal displacement of people, and economic disruptions can have a serious effect on agricultural production, markets and market chains, as market systems are destroyed by conflict situations and insecurity on roads halts commercial transport. Crop production in developing countries often is influenced by civil unrest, which affects both productivity and markets. This is the case in Africa where countries such as Angola, Burundi, the Democratic Republic of Congo, Somalia and Uganda have been or are still afflicted by civil and military conflict (Machel, 2004). In Ivory Coast, the world’s largest cocoa producer with around 35 percent of global production, recent political unrest threatened to disrupt global cocoa markets (Allison and Martinez, 2010). Production may dwindle and markets may contract in countries afflicted by war, such as Afghanistan and Iraq, and countries experiencing civil upheaval, such as those across the Middle East.

Coordinated efforts are needed to overcome these and other challenges to achieving food and nutritional security. Within this context, research into, and development of, underutilized vegetable species can have a significant role in the progress towards achieving food and nutritional security.

EXPANSION OF THE RANGE OF CULTIVATED FOOD CROPS
As the world focuses on achieving food and nutritional security, it is imperative to improve smallholder resilience in developing countries, to find new opportunities for improving global nutrition, and to ensure sustainability of the proposed solutions.

Vegetable species make a major contribution to the diets of the world, by providing needed micronutrients but ensuring variety and taste in many otherwise bland staple dishes. Some vegetables have become known globally—for example tomatoes, cucumber, carrots, and cabbage. There are many different varieties of these crops available with different colors, shapes, uses and agronomic qualities. Unfortunately, market chain players and plant breeders often put qualities such as long shelf life or disease resistance ahead of ensuring high nutrient content (and often taste). The less well-studied vegetables, so-called indigenous vegetables, often are high in nutritional content; selections from naturally occurring populations will improve agronomic traits and take consumer-preferred qualities into consideration, though there are obviously many opportunities for further improvement through proper plant breeding.

Farmers and farming communities need resilient production systems to reduce risk from climate uncertainty, support household stability, and improve livelihoods. Diversification of food production by expanding the choice and range of crops to grow is one way to increase the adaptation of agricultural production systems to climate
variability and change. When growing a range of crops, farmers reduce their level of risk as different crops have different levels of tolerance to different biotic and abiotic stresses; at least some yield usually will be harvested from a mixed cropping system when there are adverse growing conditions.

The act of diversifying the crops grown can be a risk if the wrong crops or the wrong varieties are chosen. Because small-scale farmers can rarely afford to experiment themselves, they will require evidence that new crops and varieties are based on local, reliable performance before adding new vegetables to their rotations.

Underutilized, indigenous or native vegetable species are excellent sources for diversification of production systems. Many of these species are adapted to local agroecological conditions, need low production inputs to grow, and are usually hardy and able to tolerate harsher and more difficult environments. Many do not have significant pest and/or disease problems as long as they are planted on a small scale and in mixed cropping systems and thus require less or no pesticide input. Many indigenous vegetables contain high levels of nutrients and therefore often have cultural and local food security significance. Indigenous vegetables are suitable as cash crops and as a source of readily available daily sustenance in home gardens.

**Higher food crop production**

Less well-known indigenous vegetables have not been purposefully and intensively cultivated. Nevertheless, harvests from mostly serendipitous home-growing or collecting from the wild constitutes a significant source of food for daily sustenance among many low income populations in developing countries. In Southeast Asia, for example, produce from indigenous food plants for domestic consumption and market sale is gathered from the ‘in-between spaces’ of the agricultural landscape, such as field boundaries, irrigation channels edges, swamps, and roadsides (Price and Ogle, 2008). The conscious use of adapted and appropriate production practices for these indigenous food plant species will significantly raise their importance in nutritional and food security and as a source of income.

Farmers in the northern Tanzanian village of Manyire reap benefits from growing hardy, almost forgotten, indigenous African eggplant (*Solanum aethiopicum*). Using good agricultural practices with improved varieties, such as AVRDC-developed ‘Tengeru White’ and ‘DB3’, a field of 0.2 ha can yield 300-600 kg of eggplant per week throughout the 7-month growing season (AVRDC, 2008a). Despite the promise of African eggplant as a source of nutrition and income, the availability of seed supplies to meet the demand from growers is still one of the biggest constraints in the region.

Over the past decade, increasing knowledge and understanding of the nutritional value of indigenous vegetables in Africa has resulted in rising demand, especially among the more affluent sector of the population in major urban locations. However, supply has not matched demand, partly because of lack of awareness among farmers to take advantage of the opportunities for indigenous vegetable production (Ngugi *et al.*, 2006) and the lack of quality seeds of improved varieties (Adebooye *et al.*, 2005).

**Greater resilience of production systems**

Many effects caused by climate change and climate uncertainty have been predicted and are becoming apparent. For instance, changes in rainfall patterns are
causing droughts and floods, and changes in mean temperature are leading to non-optimal growth conditions for certain crops. Water and heat stress affecting crop production will alter the dynamics of incidence and distribution (both geographic and temporal) of some insect pests and diseases, increasing the biotic stress on crop production systems (Jarvis et al., 2010). Expanding the diversity of food crops grown can mitigate the risks faced by farmers.

In many South Asian and most African countries, the flowers, tender leaves, stems and pods of Cleome gynandra (spider plant, cat’s whiskers, spider-flower) are commonly consumed as vegetables. In addition to being easy to grow, good tasting and highly nutritious, C. gynandra is a C₄ plant (Koteyeva et al., 2011). The carbon fixation mode of C₄ plants results in a more efficient photosynthesis and reduced water loss by transpiration. These characteristics cause C₄ plants to use less water per unit weight of biomass produced, and to tolerate greater water and temperature stresses, allowing C₄ plants to thrive in hot, arid environments. Spider plant, chard (Beta vulgaris), and amaranth (Amaranthus cruentus) are examples of underutilized C₄ vegetables species (Kadereith et al., 2003).

Many indigenous vegetable species have better resistance against pest and diseases compared with the more common, global vegetables such as tomato and pepper. Observations and studies from different parts of the world confirm this observation. For example, leafy indigenous vegetables such as amaranth are resistant to root-knot nematodes in Bangladesh (Coyne et al., 2009). Spider plant is not seriously affected by the prevalent relatively high incidence of whiteflies, beetles, leaf-miners and brown coreid bugs in Kenya (Sithanantham et al., 2003). In Sudan, an indigenous vegetable melon (Cucumis melo agrestis) was found to be much more resistant to multiple pests (leaf miners, fruit flies) and diseases (Fusarium wilt, powdery mildew, Zucchini yellow mosaic virus, Cucurbit aphid-borne yellows virus) compared with other cultivated melon species (El Tahir and Yousef, 2011).

Expanding the range of food crops by including indigenous vegetables in production systems is an important strategy to ensure a resilient agricultural production system.

**Income generation**

Poverty, hunger and malnutrition are intertwined to form a vicious cycle among the greater part of the world’s population. Poverty causes the lack of buying power to obtain adequate food, which leads to hunger and malnutrition, which in turn causes poor health, low energy, and mental impairment. These effects reduce a person’s ability to work and learn normally, leading to greater poverty and even greater hunger.

In southwest Nigeria and western Kenya, indigenous vegetables have an important income-generating role among the poor (Adebouye and Opabode, 2004 and Abukutsa-Onyago, 2003 as cited in Shackelton et al., 2009). Indigenous vegetables such as Solanacio biafrae (worowo), Celosia argentea (cockscomb), amaranth, and Solanum macrocarpon (African eggplant) can be cultivated with a very small capital investment, providing a significant opportunity for many poor families to earn a living when the produce is sold at a profitable price.

Amaranth (A. cruentus, A. hybridis, A. dubius) is a fast growing crop with practically no pest or weed problems and is very easy to grow. Settled Maasai farmers on
the slopes of Mount Meru, Tanzania cultivate improved varieties of amaranth that have more palatable, softer and sweeter leaves. Local buyers purchase the crop by the plot, which they harvest and transport themselves. An area of only 500 m² of land can earn a farmer US$250 a year as a valuable source of supplementary income. The abundant yield can sometimes meet the high market demand in Nairobi, Kenya, 250 km away from the production site. Amaranth now appears on the menu of small local hotels catering to tourists and conferences, and can be found in major supermarkets in Nairobi. The strong demand is also helping some seed companies develop, expand and thrive and is contributing to the growth of the seed production sector (AVRDC, 2008b).

In addition to providing food security for poor households, Weinberger (2007) found that in Eastern Africa and Southeast Asia indigenous vegetables are becoming an increasingly attractive food group for the wealthier segments of the population. Capturing this growing market will strengthen the role indigenous vegetables play in generating income for poverty alleviation, and will provide farmers with a means to break the vicious cycle of poverty and hunger.

**Diversified diets**

When income is below the threshold level for food security, poverty drives food intake toward cheaper, higher calorie content, carbohydrate-dominated diet. The same negative tendency occurs when incomes rise above a critical level, with a tendency to consume energy-dense foods such as meat, fats, and oil (Keatinge et al., 2010). Either by need because of poverty, or by choice because of wealth, an imbalanced diet lacking essential micronutrients is at the core of many serious health problems. Anemia due to iron deficiency may cause complications in pregnancy, maternal mortality and premature birth; vitamin A deficiency causes eyesight problems and impaired resistance to infection. In Africa alone, approximately one-third of the diseases suffered by the population are believed to be related to micronutrient deficiency, mainly iron, vitamin A, zinc and iodine (Benson, 2004). As vegetables are an excellent source of micronutrients, diversifying diets by including adequate amounts of vegetables of at least 200 g/person/day as recommended by the World Health Organization is crucial for good health. According to the Food and Agricultural Organization, average vegetable consumption in sub-Saharan Africa was only 86 g/person/day (FAOSTAT, 2004), while in South Asia it was 171 g/person/day and in Southeast Asia 144 g/person/day (FAOSTAT, 2010).

One of the most valuable benefits of indigenous vegetables is their high content of vitamins, minerals, fiber and other micronutrients essential for human health. Indigenous vegetables contain high levels of β-carotene and vitamin C, and in general have higher vitamin E, folate, calcium, iron, and zinc content and higher antioxidant activity compared with global vegetables (Yang and Keding, 2009). Leaves of cowpea (*Vigna unguiculata*), baobab (*Adansonia digitata*), jute mallow (*Corchorus olitorius*), African nightshade (*Solanum scabrum*), amaranth, spider plant, moringa (*Moringa oleifera*), pumpkin (*Cucurbita spp.*) and cassava (*Manihot esculenta*) are very nutritious and contain relatively high levels of β-carotene. Table 1 shows various indigenous vegetables that contribute a significant percentage of recommended nutrient intake for pregnant women during the first trimester.

Including indigenous vegetables into the diet thus has great potential to combat malnutrition and improve overall health. Lower income groups for whom indigenous
vegetables are more affordable than other global vegetables or animal meat products will benefit greatly through increased availability of indigenous vegetables. This can be achieved by including indigenous vegetables in diversified production systems.

ADDRESSING THE CHALLENGES AND HARNESSING THE OPPORTUNITIES

Despite the demonstrated advantages of indigenous vegetables and their potentially significant role in food and nutritional security, constraints to their production and consumption leave them on the margins of agriculture. When indigenous species cannot compete with introduced species, it is not due to the lower potential of the indigenous species, but because of the lack of research and development effort being put into them (Javier, 1993). The scientific community can contribute to the drive to move indigenous vegetables into the mainstream of important and fully capitalized food crops. By preserving and utilizing biodiversity to breed superior varieties, by sustaining the availability of high quality seeds, by enhancing the traditional knowledge of production through improved cultivation practices, by promoting benefits of consumption, and by improving food preparation methods for increased nutrient bioavailability and intake, research and development efforts can contribute to more rapid progress toward achieving food and nutritional security.

Biodiversity conservation and utilization

Indigenous vegetables are a very diverse group and include many species. This genetic biodiversity is a treasure of promising desired characteristics yet to be mined. Priorities set by governmental policies often focus on more well-known vegetables species at the expense of less well-known ones. If there is no conscious effort to conserve indigenous vegetable biodiversity and if the predicted shifts of earth’s agroecological conditions due to climate change and variability materialize, the diversity of less well-known but versatile and valuable indigenous vegetables will erode and many species may face extinction. It is imperative to collect and conserve the diversity of indigenous vegetable species.

Over the years, the focus of the collection and conservation of genetic resources at AVRDC – The World Vegetable Center has shifted to include vegetable species of regional or local importance, with special attention given to indigenous vegetables. The Center’s current germplasm acquisition policy is to prioritize genetic resources at risk of erosion or extinction and to fill gaps in the existing collection as identified by AVRDC breeders. The Center’s genebank conserves more than 12,000 accessions of 200 indigenous vegetable species from South Asia, Southeast Asia, and Africa. To ensure the safety of the collection, accessions of many crops such as water spinach (Ipomoea aquatica), hyacinth bean (Lablab purpureus), African and Asian eggplant and its wild relatives, and African nightshade are duplicated in the Svalbard Global Seed Vault in Norway and in the National Agrobiodiversity Center of the Republic of Korea.

The Center is working with partners to collect and conserve the genetic diversity of slippery cabbage (Abelmoschus manihot), a popular, highly nutritious vegetable that is indigenous to China, the Indian subcontinent, Malaysia, Australia and the Pacific islands, and which is almost always propagated vegetatively in the Pacific region. Collaborating with national partners, the Center strengthens in situ conservation of jute mallow
(Corchorus olitorius), bottle gourd (Lagenaria siceraria), ridged gourd (Luffa acutangula) and cucumber (Cucumis sativus) in the Philippines through community-based conservation and multiplication to ensure availability of good quality seed for home gardens and commercial production.

Diversity in genetic resources can be targeted as building blocks for breeding efforts to develop improved, superior lines of crops with desired characteristics. A relatively high number of germplasm accessions from the Center’s genebank are requested by and distributed to in-house scientists, as well as breeders in national programs and the private sector, indicating vibrant research and development activities with public and private sector partners.

The collected accessions of indigenous vegetables in the Center’s genebank are international public goods and available to all under a Material Transfer Agreement. To date, the Center has distributed genetic resources to national agricultural research and extension systems, nongovernmental organizations, individuals, public and private companies, and universities in 59 countries. Responding to requests from public and private partners in Africa, in 2010 alone the Center’s genebank distributed 264 accessions of spider plant, Ethiopian mustard (Brassica carinata), okra (Ablemoschus esculentus), African eggplant, African nightshade, amaranth, jute mallow, roselle (Hisbiscus sabdariffa), moringa, hyacinth bean (L. purpureus), slender leaf rattlebox (Crotalaria ochroleuca), velvet bean (Mucuna pruriens), cockscomb or Lagos spinach (Celosia argentea), and Malabar spinach (Basella alba), indicating a growing interest for better use of indigenous vegetables.

To encourage greater use of indigenous vegetables, various species are included in the Center’s healthy diet gardening kits, which are targeted to local communities in Africa and Asia. Over the past few years, more than 11,000 households have received and utilized the kits, which have helped to increase the popularity of indigenous vegetables. Because they are easy to grow, yield quickly and can tolerate difficult environments, indigenous vegetables have been selected for inclusion in the Center’s vegetable seed kits for immediate rehabilitation of vegetable production among households affected by natural disasters. To date the seed kits have been distributed to earthquake, typhoon and tsunami survivors in Haiti, Taiwan, and Sri Lanka and Indonesia, respectively.

**Breeding and selection for desired characteristics**

Selection from within natural populations of indigenous vegetables is a quick way to make tremendous gains in terms of agronomic characteristics, consumer qualities and tolerance to biotic and abiotic stress. With a longer timeline, conventional breeding can also make rapid gains to develop good quality foundation seed for the public and private seed sector and to ensure preferred characteristics are not lost if farmers plant seed they have saved.

Examples of improved indigenous vegetable lines are amaranth lines ‘White Elma’ and ‘Green Gina’ selected by AVRDC – The World Vegetable Center. These lines have a shorter growing period (28 days compared with 40 days for many traditional lines) and softer, sweeter leaves than the traditional varieties, which have much tougher leaves that require a cooking time of up to 40 minutes. Farmers and households in Arusha, Tanzania appreciate the new varieties, which have a cooking time as short as 10 minutes.
This short cooking time retains more of amaranth’s nutritional value and also helps save fuel required for cooking (AVRDC, 2008b).

In selecting lines of indigenous vegetables, farmer participation is a prerequisite to ensure adoption. AVRDC – The World Vegetable Center holds seed fairs and demonstrations where farmer and consumer participation helps the Center determine the right characteristics to incorporate into the elite lines. To ensure the lines are adapted and grow well under actual conditions farmers face, the Center uses farmer participatory trials as a routine part of the varietal development activities. From the participatory variety trials in several villages in Niger, farmers have selected high yielding roselle lines with good agronomic characteristics; roselle lines ‘Samandah’ and ‘L28’ are the highest yielders. Participatory trials also provided an opportunity to convince farmers that roselle can be grown during the dry season. Now, farmers in Niger are considering adding roselle to their portfolio of vegetable crops.

**Increased seed availability**

One of the main constraints to increasing the utilization of indigenous vegetables is the current inability to assure a reliable supply of quality seeds. While farmer-saved seed is useful to permit local production, the participation of the private seed sector is vital to provide reliable quality and to extend the growing area. AVRDC works closely with the public and private seed sectors to promote seed production of improved indigenous vegetable lines.

When improved varieties of indigenous vegetables meet the needs of both producers and consumers, demand for the crops can increase dramatically. Sufficient quantities of quality seeds of the improved varieties must be available to allow farmers to capitalize on new market opportunities. The increasing demand for quality seed has encouraged the private sector in East Africa to produce and market seed of several indigenous vegetables including African eggplant and amaranth. The AVRDC-developed sweet tasting African eggplant ‘DB3,’ ‘AB2’ and ‘RW14’ outyield most traditional bitter-tasting varieties and are creating a new market among urban consumers in Tanzania. Local seed companies have started scaling up seed production to meet producer demand (AVRDC, 2008a).

**Improved production practices**

Improved production practices generally improve yields of agricultural crops—an effect that should be even more pronounced with some indigenous vegetables, many of which were simply harvested from naturally growing wild plants. Nonetheless, it is important to understand the agronomic requirements of indigenous vegetables including soil fertility needs, water requirements, and optimum seasonal growing periods. An awareness of biotic constraints also is needed to avoid build-up of insect pests or pathogens and to ensure compatibility with other crops in the production system.

Proper pre- and postharvest handling ensures quality products for market and consumption. Appropriate production and postharvest techniques will facilitate harvesting, minimize contamination with microorganisms, and help the farmer deliver quality products to the market.

An example of quality products creating high demand through appropriate pre- and postharvest handling is the marketing of kale (*B. oleracea*) in Nairobi, Kenya. By
adding value through producing and handling kale using hygienic considerations (cultivation on uncontaminated soil using water of adequate quality, ensuring that the harvested produce is clean without contaminating soil and other debris), the produce is bought by supermarkets for onward sale. Consumers’ willingness to pay for safer kale in supermarkets is 39% higher than those who buy kale in wet markets (Ngigi et al., 2011). The high quality products also are in demand by market traders, who buy the produce from supermarkets for resale in street markets.

Value-addition is also important. Some indigenous vegetables with a short shelf life can be processed to add value. Processing can include drying, salting, fermenting, pickling, canning and production of juice, for example, roselle juice. In addition to expanding the usage of the vegetables and to prevent market saturation during peak harvest seasons, processing also can increase farmers’ income, as in many cases the processed products fetch a higher market value than the fresh produce. In Vietnam for example, the price of pickled Chinese mustard (B. juncea) was almost twice the price of fresh, unprocessed Chinese mustard (Than et al., 2002).

Promoting indigenous vegetables

Poor households in Central and Northeastern Tanzania fulfill their daily requirement for micronutrients, especially vitamin A and iron, by relying on consumption of indigenous vegetables (Weinberger and Swai, 2006). Local people in many other locations already may be aware of the benefits of indigenous vegetables. However, promotion is needed to extend the growing area, and to provide information on the benefits of consuming indigenous vegetables to potential new growers and consumers. Promotion of indigenous vegetables is done through demonstrations and field days, through promotion by private sector seed companies, and by working with community health groups.

AVRDC promotes indigenous vegetables through schools, where children are able to grow vegetables in garden plots set up at the schools. The harvested vegetables are consumed through the school lunch program. This has been particularly effective in the Philippines. Recently, a nationwide campaign ‘Oh My Gulay’ was implemented to encourage vegetable consumption in the country, including indigenous vegetables. The school garden program is now receiving support from policy makers with all schools in the Philippines being encouraged to participate. This effort received even greater promotion when the Philippines school garden program was featured on the international Cable News Network (CNN, 2011).

Indigenous vegetables also are included in AVRDC’s healthy home gardening kits distributed in India and Africa. A model 6 x 6 m² home garden plot has been developed for two districts in India with different sets of cropping sequences; the plot can provide an adequate amount of vegetables for a family of four year-round. The home garden model is being modified and adapted to other regions. Vegetable seed kits developed by AVRDC for disaster response and nutrient relief mostly consist of indigenous vegetable crops. Easy to grow and with low input requirements, these crops can be cultivated under natural and survivors’ conditions after a disaster strikes. The vegetable kits are provided to alleviate nutritional crises following natural and man-made disasters, and to help enable immediate rehabilitation of vegetable production in the most vulnerable farming communities in disaster-affected areas.
Better food preparation methods

Food preparation is a critical aspect of ensuring beneficial phytochemicals of micronutrient-rich vegetables can be taken up by the body. Vegetables usually are cooked for consumption. Cooking changes the concentration and bioavailability of health-promoting compounds in vegetables. Positive and negative effects have been reported as influenced by the type of processing, the type of vegetable used, and its nutritional characteristics. Cooking also changes the physical properties of vegetables, such as texture and color, factors that strongly impact consumer decisions in purchasing certain produce. Miglio and co-workers (2008) evaluated the effect of three cooking practices (boiling, steaming, and frying) on phytochemical contents and total antioxidant capacities of carrots, zucchini, and broccoli and found that antioxidant activity was increased in all cooked vegetables compared with raw vegetables, most likely due to softening of the tissues and increased extractability of compounds from which antioxidant compounds are derived. The texture of steamed vegetables was better than boiled vegetables, but boiling cause discoloration. Frying had the lowest impact on softening, but was less efficient in retaining antioxidant compounds. Cooking in water preserved the antioxidant compounds, particularly carotenoids, better than the other two methods in all vegetables tested. These results may vary from one vegetable type to another and more research on food preparation methods is needed, especially for the seldom-researched indigenous vegetables.

Apart from retention of phytochemicals and potential increase in their bioavailability, the way new products are presented has a major impact on the adoption, production, and consumption of indigenous vegetables. When promoting a new vegetable to farmers and consumers, food preparation methods must be available at the same time, with recipes adapted to local tastes and ingredients; the dishes also must be attractively presented and affordable. AVRDC has developed numerous recipes with local partners to meet local tastes and cooking styles while ensuring bioavailability of micronutrients. The Center has published a collection of high-iron, good-tasting mungbean recipes from South Asia combining whole or split dehulled mungbeans with a range of different vegetables, including indigenous vegetables, to enhance bioavailability of iron (Subramanian and Yang, 1998). More recently, a collection of attractive and nutritious recipes of indigenous vegetables has been compiled (Lin et al., 2009).

CONCLUSION

Crops diversification for food production increases the adaptation of agricultural production systems to climate variability and change. Underutilized, indigenous vegetables are excellent sources for diversification as they are locally well-adapted, need low levels of inputs for cultivation, and sometimes tolerate harsh environmental conditions. At small-scale production levels and in mixed cropping systems indigenous vegetables usually do not have significant insect pest and disease problems and require hardly any pesticide application. Moreover, many indigenous vegetables contain high levels of micronutrients and thus are an important component to achieve food and nutritional security. These valuable species provide a source of readily available daily sustenance in home gardens and are also suitable as cash crops as evidenced by many successful examples in Africa and Asia. Research undertaken by AVRDC has led to the
release of many promising indigenous vegetable lines on both continents. Availability of high quality seed of outstanding lines is an essential requirement for the growth of this sector and AVRDC has trained and encouraged private sector seed companies to step into this niche and supply farmers with quality seed. Major research and development efforts are needed in the area of breeding and selection of new lines, production and postharvest technologies, marketing and food preparation to guide farmers in successfully cultivating and marketing indigenous vegetables. Consumers need guidance in preparing vegetables as a nutrient-dense food component to achieve more balanced diets and to improve their health.

Table 1. Percentage of recommended nutrient intake for pregnant women during the first trimester, contributed by 100 g each of six indigenous vegetable crops.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Protein</th>
<th>Vitamin A</th>
<th>Iron</th>
<th>Folate</th>
<th>Zinc</th>
<th>Calcium</th>
<th>Vitamin E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slippery cabbage</td>
<td>6</td>
<td>106</td>
<td>5</td>
<td>30-177</td>
<td>11</td>
<td>18</td>
<td>58</td>
</tr>
<tr>
<td>Moringa leaves</td>
<td>7</td>
<td>146</td>
<td>11</td>
<td>49</td>
<td>5</td>
<td>10</td>
<td>65</td>
</tr>
<tr>
<td>Amaranth</td>
<td>9</td>
<td>160</td>
<td>6</td>
<td>31</td>
<td>6</td>
<td>32</td>
<td>17</td>
</tr>
<tr>
<td>Jute mallow</td>
<td>10</td>
<td>198</td>
<td>12</td>
<td>21</td>
<td>0</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Nightshade</td>
<td>8</td>
<td>101</td>
<td>13</td>
<td>10</td>
<td>9</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>Cowpea leaves</td>
<td>8</td>
<td>193</td>
<td>6</td>
<td>27</td>
<td>3</td>
<td>54</td>
<td>101</td>
</tr>
</tbody>
</table>

*) RNI for pregnant women, 1st trimester: protein 60 g, vitamin A 800 ug RE, iron 30 mg, folate 600 ug, zinc 11 mg, calcium 1,000 mg, vitamin E 7.5 mg a-TE (WHO/FAO, 2004)

**) Nutrient data source: AVRDC indigenous vegetables nutrient data (unpublished data)

REFERENCES


