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ORIGINAL PAPER

The importance of vegetables in ensuring both food and nutritional security in attainment of the Millennium Development Goals

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Abstract A nutritious and varied diet is a critical means by which good health can be maintained. Consumption of less than 200 g of vegetables per person per day in many countries today is common and this low amount, often in conjunction with poverty and poor medical services, is associated with unacceptable levels of mortality and malnutrition in preschool children and other vulnerable groups. An increase in the availability, affordability and consumption of nutrient-dense vegetables and pulses is one way malnutrition may be substantially reversed—yet nutritional security appears to be less valued than food security by key decision makers, and vegetable crops thus receive inadequate research investment. Opportunities exist for the poor to improve their access to vegetables, particularly if they are willing to grow home gardens. Research continues on defining appropriate nutrient-dense vegetables for such activities, but these efforts may be compromised by failure to adopt good agricultural practices, resulting in contamination and unhealthy produce for producers and consumers. The scientific community is ready to play its role in battling malnutrition and hunger, but unless the political resolve can be found to support the causes of both food and nutritional security together, it is unlikely that the Millennium Development Goals will be achieved in a timely fashion. Redressing the current imbalance in agricultural investment can improve efficiency in food production and ensure nutritious diets can be a reality for all people.

Keywords Nutritional security · Indigenous vegetables · Nutrient-density · Malnutrition · Research funding

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Introduction

The numbers of malnourished people globally may well exceed 2–3 billion (FAO 2009). This includes at least one billion undernourished people in South Asia and sub-Saharan Africa who have diets lacking not only sufficient carbohydrates and proteins but also essential minerals and vitamins. Diets of the remaining two billion are of limited nutritional quality, with excess oils and carbohydrates and insufficient proteins, minerals and vitamins (Popkin 2007; Mayer-Foulkes 2011). These diets are clear precursors of obesity-derived ill health associated with non-communicable disease conditions such as type II diabetes, hypertension and cardiac issues (Yach et al. 2006), which are significant causes of mortality and cost health care systems hundreds of billions of US dollars (Hogan et al. 2003). Countries with the highest number of pre-diabetic or diabetic people presently include China, with about 10% of its population affected; South Asia, with probably more than 20% of the world's diabetic patients; and the USA. Other hotspots in terms of the proportion of the population at health risk include the Arabian Gulf countries and the island nations of the south and central Pacific (International Diabetes Federation 2009). This paper describes the importance of nutritious and varied diet, the global

advances that have been made to meet the nutrition needs of the poor, and the challenges that remain in order to achieve food and nutritional security for everyone.

How lack of sufficient vegetables seriously affects human health

The mortality rate for children under five is a leading indicator of child health and overall development in countries. Child malnutrition—as measured by the percentage of underweight children aged under 5 years—is an important indicator for monitoring the nutritional status and health of populations. Both are used as indicators in progress toward attainment of the Millennium Development Goals (MDGs).

The amount and quality of food intake affects a person's nutritional status. There is a highly significant ($p<0.001$) association ($r=-0.52$) between vegetable availability per person and the mortality rate of children under five (Fig. 1). This factor has the potential to have a substantial effect once vegetable availability rises above the threshold of 200 g of vegetables per person per day. The same low availability threshold is also strongly associated ($r=-0.53$, $p<0.001$) with underweight children under five.

For example, in the Philippines where vegetable availability is around 175 g per person per day (FAOSTAT 2010) child mortality *per se* is commendably low—and yet the percentage of children under five that are stunted by malnutrition is considerably higher than in many other countries with better vegetable availability. Heaver and Hunt (1995) demonstrate that this problem has been recognized for the last 15 years but has yet to be adequately addressed.

In Niger, one of the poorest countries in the world, vegetable availability is only about 121 g per capita per day (FAOSTAT 2010), equivalent to 60% of the World Health Organization's (WHO) recommended amount. The poor health and nutritional status of Niger's population is indicated by the high preschool mortality rate (230/1,000) and the large percentage (43%) of underweight children under five (WHO 2010a, b). Similar associations between low vegetable availability with high mortality rates and high percentages of underweight children less than 5 years of age also occur in other poor countries such as Mali and Tanzania (Fig. 1).

Countries with daily per capita vegetable availabilities of less than 200 g, but with lower child mortality rates under 5 years of age (<50/1,000) and lower percentages of underweight children under 5 years of age (<10%) include Thailand, Malaysia, Costa Rica, Colombia, Peru, Panama, Honduras, and Nicaragua. Although vegetable availability is insufficient, people in these countries probably have better overall economic status and thus have access to other nutritious foods and health care to compensate for the lack of vegetable consumption.

Clearly, a lack of vegetables in peoples' diets has serious health consequences, which will directly impinge on the attainment of many of the MDGs. Low vegetable consumption has direct implications for MDG 1 (eradication of extreme poverty and hunger) and has an important influence on MDG 4 (reduction in child mortality) and MDG 5 (improvement of maternal health).

Malnutrition in childhood impairs intellectual functions, but some of the damage to the brain caused by malnutrition

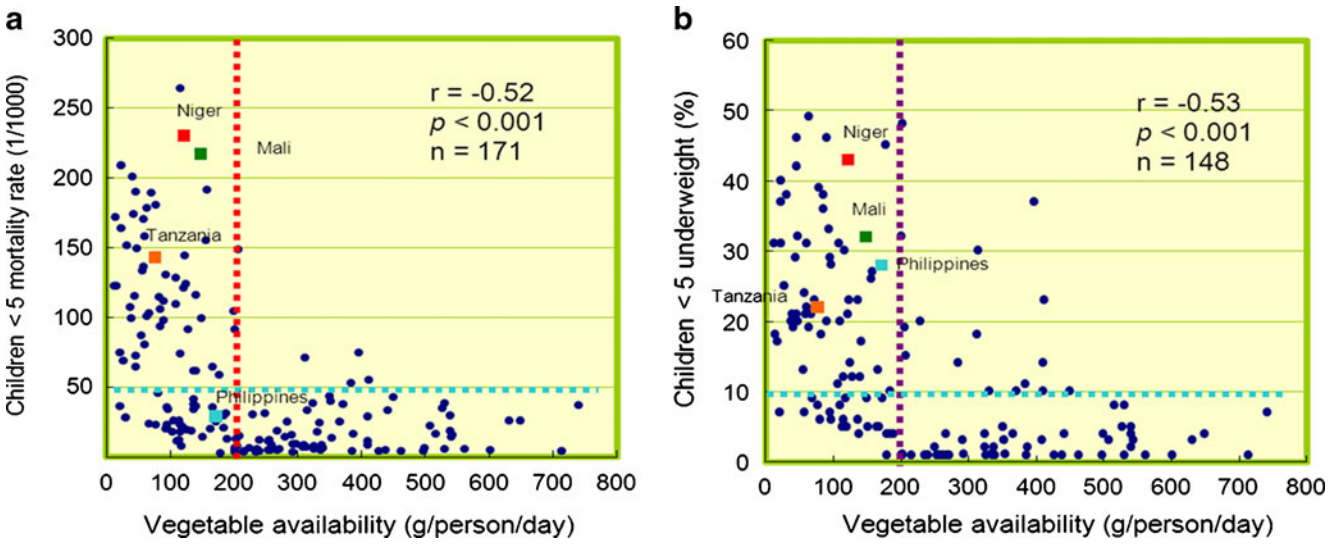

Fig. 1 National vegetable availability as a factor in the health status of vulnerable groups associated with (**a**) preschool mortality and (**b**) childhood (<5 years) undernutrition. Data source: vegetable availability: FAOSTAT 2010; children under five mortality rate and underweight: WHO 2011a, b

may be reversed (Brown and Pollitt 1996). The timing of malnutrition in early childhood is a critical factor in determining subsequent cognitive development. Glewwe and King (2001) suggest that malnutrition in the second year of life may have a larger negative impact on cognitive development than malnutrition in the first year. This is an important factor to be considered in the benefits to be derived from MDG 2 (achievement of universal primary education). Attainment of this goal would be seriously undermined if many of the children attending primary school were also suffering from reduced IQ (Intelligence Quotient) as a result of stunting from malnutrition, and were unable to benefit from improved educational opportunities (Food and Nutrition Research Institute (FNRI) 2008).

There is recent evidence that a poor diet associated with high fat, sugar and processed food content in early childhood may be associated with small reductions in IQ in later childhood, while a healthy diet, associated with high intakes of nutrient rich foods described at about the time of IQ assessment may be associated with small increases in IQ (Northstone et al. 2011). Belot and James (2009) in the United Kingdom also reported significant educational improvements of pupils in the subjects of English and the sciences in primary schools that were part of the "Feed Me Better" campaign (led by chef Jamie Oliver), which shifted school meals away from low-budget processed foods toward healthier options with more fruit and vegetables.

The Asian Development Bank (ADB 2006) reports that surveys of schools in south Luzon in the Philippines indicated between 27% and 37% of children were either underweight or stunted; similar figures were reported by the Philippines Food and Nutrition Research Institute (FNRI 2008) and historically by Heaver and Hunt 1995. By introducing the growing of vegetables as part of the school curriculum in three schools in the Philippines, some progress was achieved in changing diets and educating the parents of pupils (Asian Development Bank ADB 2006). Elements of this successful project have now been introduced into all 42,076 public primary and secondary schools of the country through the "*Gulayan sa Paaralan*" (= Vegetable Gardens in Schools) program, operative through to the year 2016 under the Philippine Department of Agriculture's Administrative Order Series 2011, No. 15 (Department of Agriculture 2011). Similar initiatives were conducted in Negros Occidental province in 1984 during a national economic crisis, when 250,000 sugar workers were displaced and 25 children were dying each month from malnutrition; in response, home gardens for intensive cultivation were developed and widely promoted to produce adequate vegetables for a family of five or six. Within 2 years of introducing the program, the rate of malnutrition dropped from 40% to 25%. The number of gardens increased at an average rate of 21,000 per year, and 50–75% of vegetables produced were consumed by family members (Midmore et al. 1991). The program was successful, low-cost, and instituted province-wide. But it was also low profile, and the successful lessons of home vegetable gardens have had to be re-learnt by a new generation of politicians. Happily this seems to be the case as shown by the *Oh my Gulay!* campaign currently being promulgated by Senator Angara and supported by many prominent Filipino citizens from the media, entertainment and sporting worlds in order to promote increased vegetable consumption for good health (OMG 2011).

Ways of overcoming vitamin and mineral deficiencies can take several forms. In the case of vitamin A deficiency amongst children, the trend amongst medical practitioners and donor agencies favors supplementation with vitamin A tablets. This approach is an effective answer to deficiency in the short term but hardly seems sustainable in the long term. Other options include biofortification of staple crops as promulgated by the Harvest Plus program of the Consultative Group for International Agricultural Research (HarvestPlus 2010). This approach has merit but is likely to require long-term research investment to fully pay off. Its exemplar crop, orange fleshed sweet potato, has been shown to be an excellent source of vitamin A and is in the process of widespread adoption in countries such as Mozambique and Uganda (Naico and Lusk 2010). However, as obesity is a growing problem associated with vitamin malnutrition, providing a carbohydrate-based source of vitamin A is perhaps not a perfect solution. In contrast, increasing dietary diversity to include more pulses, additional green leafy and orange vegetables, and other nutrient-dense foods seems to be a more logical answer. Although de Pee and Bloem (2007) have indicated that there are difficulties associated with the bioavailability and bioconversion of carotenoids into vitamin A, they nevertheless still recommend dietary diversity with fruit and vegetables as part of an overall program to overcome vitamin A deficiency. This is particularly important, as fruit and vegetables are sources of a whole range of additional vitamins, minerals and other beneficial dietary components such as folate that make important contributions to human health (Table 1).

Newly pregnant women need to pay close attention to their diets if they are to achieve the World Health Organization and Food and Agriculture Organization's jointly recommended intake of minerals and vitamins (FAO/WHO 2004) (Table 1). Staple cereals provide only a very minor contribution of protein, vitamins A and E, iron, zinc, calcium and folate. If they are meat or fish eaters, they will receive protein; if they regularly consume pulse crops they will obtain not only protein but also many

Table 1 Recommended nutrient intakes (RNI[a]) for women in the first trimester of pregnancy and percentage nutrient intake from 100 g of food[b]

	Protein	Vitamin A	Iron	Folate	Zinc	Calcium	Vitamin E
RNI for pregnant women (1st trimester)							
	60 g	800 μg RE[c]	30 mg	600 μg DFE[d]	11 mg	1,000 mg	7.5 mg α-TE[e]
Percentage of RNI from 100 gm food							
	%						
Rice	0	0	1	2	4	0	0
Cassava (root)	2	0	1	5	3	2	0
Millet	6	0	2	14	8	0	0
Meat (chicken)	37	0	3	1	14	1	3
Mungbean	40	2	22	104	24	13	7
Vegetable soybean	18	2	13	28	13	4	78
Cabbage	3	1	1	10	2	4	2
Tomato	2	18	1	3	2	1	7
Slippery cabbage	6	106	5	30–177	11	18	58
Moringa leaves	7	146	11	49	5	10	65
Amaranth	9	160	6	31	6	32	17
Jute mallow	10	198	12	21	0	36	36
Nightshade	8	101	13	10	9	21	28
Vegetable cowpea leaves	8	193	6	27	3	54	101

[a] RNI: data souce: FAO/WHO 2004. RNI for populations of pregnant women (1st trimester) and diets of low iron and zinc bioavailabilty

[b] Nutrient data sources: AVRDC nutrition laboratory and USDA nutrient database (USDA 2010)

[c] RE: retinol equivalent: 1 μg RE = 6 μg β-carotene = 12 μg α-carotene

[d] DFE: dietary folate equivalent, 1 μg DFE=0.6 μg of folic acid supplement

[e] α-TE: α-tocopherol equivalent; 1 mg α-TE = 1 mg α-tocopherol = 1 mg *d*-α-tocopherol = 0.5 mg *d*-β-tocopherol

important mineral contributions as well (Tables 1 and 2). However, the contribution of vitamins A and E from pulses is relatively small and this is also true of certain common vegetables such as white cabbage and even tomato. Yet it is abundantly clear that there are many nutrient-dense vegetables commonly eaten in Asia and Africa that are major sources of these vitamins (Table 1). Having a nutritious diet that includes a diversity of grains, pulses, fruit and nutrient-dense vegetables would be a common-sense approach to good health, especially during pregnancy. To avoid specific foetal abnormalities, such as neural tube defects, a substantial amount of folate is required in women's diets; this can be provided by both pulses (Table 2) and specific nutrient-dense green leafy vegetables (Koebnick et al. 2001; Bailey 2000). It is notable that one of the principal vegetables of South Pacific communities, *Abelmoschus manihot* (slippery cabbage, *aibika*, *bele*), has an extremely high folate content (AVRDC nutrition lab, unpublished data).

Dietary diversity is needed to meet WHO recommendations and relates to nutrient adequacy and dietary quality. Dietary Diversity Scores can be used as a food and nutritional security indicator (Ruel 2003; WHO 2010c), whereas the current policy of supplementation promulgated by international donor agencies, in which vitamin pills are provided by medical practitioners for the first 1,000 days of an infant's life, may be missing an important element if the mother's diet does not include sufficient pulses and vegetables. This matter is made more acute because many women who are pregnant for the first time may be unaware of the nutritional needs of pregnancy in the first trimester and may not seek suitable medical support until it is too late. Should their diets in this trimester be inadequate in vitamins, minerals and folate, it is possible that irrevocable foetal damage already may have occurred and the likelihood of transgenerational transfer of malnutrition is increased. National health authorities must strongly emphasize that young women who are about to enter their reproductive years should receive the family's best and most diverse food, including sufficient fruit and vegetables.

Why are vegetable availability, cost and nutrient quality not national research and development priorities?

Low vitamin and mineral density for common worldwide vegetables such as cabbage and tomato is evidence of a historical trend (Davis and Riordan 2004) in which breeding, principally by large and medium sized seed companies

Table 2 Nutritional value of some major food legumes (per 100 g fresh weight)

	Dry matter g	Protein g	Total lipid g	Fiber g	Calcium mg	Iron mg	Zinc mg	Vit C mg	Folate µg	Vit A µg RE
Mungbeans	91.0	23.9	1.2	16.3	132	6.7	2.68	4.8	625	11.4
Soybeans, green	32.5	13.0	6.8	4.2	197	3.6	0.99	29	165	18.0
Soybeans, mature	91.5	36.5	19.9	9.3	277	15.7	4.89	6	375	2.2
Chickpeas	88.5	19.3	6.0	17.4	105	6.2	3.43	4	557	6.7
Peanuts	93.5	25.8	49.2	8.5	92	4.6	3.27	0	240	0
Cowpeas	89.0	23.9	2.1	10.7	85	10.0	6.11	1.5	639	3.3

Data source: USDA nutrient database (USDA 2010)

producing hybrid seed, has seemingly undervalued the nutritional component of some vegetable crops (Table 1). Other important marketing qualities such as shelf life, appearance and productivity have dominated breeding considerations. This does not have to be the case, as is evident from many open-and self-pollinated vegetable lines available from the breeding programs of AVRDC–The World Vegetable Center and other public-domain partners. These programs seek to maintain a high content of beta carotene, a vitamin A precursor, in crops such as tomato, pumpkin, and sweet pepper. These breeding programs actively seek and select genes to ensure either high carotenoid or flavonoid content, thus enabling the production of potential parents for hybrid material capable of reversing modern commercial trends (Hanson et al. 2004; AVRDC 2011).

Consuming nutrient dense vegetables is a first step along the road to overcoming malnutrition (Yang et al. 2007), but it is necessary to recognize that issues of cost and local availability can curtail consumption. Nutrient bioavailability and retention in the body also depends on the mode of cooking. Much of the vitamins and minerals in vegetables may be lost or merely transit through the body without full absorption if inappropriate cooking methods are used in food preparation. Improved domestic science/home economics disciplines are thus vital additional requirements to agricultural research efforts if nations are to effectively value vegetables and advocate their potential benefits for consumers' health. For example, Vijayalakshi et al. 2003 have shown that improved recipes and cooking methods for mungbean can substantially increase the iron and protein digestibility in meals fed to young women in India.

A lack of statistical information on vegetable production and consumption hides their vital importance to community nutrition. Collection of production and consumption statistics is hampered by the large number of vegetable crops involved, substantial production in home gardens for domestic consumption, and the sale of vegetables through informal local fresh markets. In contrast, local production statistics for crops such as wheat or rice are usually collected at local mills or grain stores, and can be fairly easily be aggregated up to the national level. Thus the importance of the wheat crop per nation is reasonably well-understood in terms of area and yield and is therefore valued both nationally and globally. These figures are reported annually to the FAO and interpreted by other agencies such as the International Center for Wheat and Maize Research (CIMMYT) in Mexico (Dixon et al. 2009). The paucity of similar types of statistics for vegetables makes the case much harder to argue for the importance of such crops, despite the fact that their dietary value is evident and their role in the provision of wholesome, tasty and attractive meals is also well-understood in most kitchens (Keatinge et al. 2010).

Horticultural research, with the exception of viticulture and some very high value industrial crops, is often the least regarded when agricultural research funding is allocated. Since the days of the Green Revolution of the late 1960s and early 1970s, the lion's share of funding continues to be apportioned to basic staple crops. The concern of most politicians with food security usually translates into a concern for staple crops such as maize, wheat and rice. A substantive re-evaluation of the relative proportion of overall agricultural research funds presently going to horticulture and tertiary horticultural education is urgently required. The decline in supply of suitably trained disciplinary specialists and the operational funds to make them useful in research is becoming a serious limiting factor in addressing the acute problems of vegetable production worldwide.

In recent decades, prices of fruit and vegetables have risen faster than those of bread or rice, and have rapidly grown beyond the reach of the poor so that fresh produce is no longer regularly purchased and consumed (Aguilar 2005; Cambodia Development Research Institute 2008). High prices for staples in 2008 forced low income households in many parts of the world to reduce the diversity of their diets and intakes of "expensive" foods such as meat, fruit, and vegetables, and to eat fewer meals per day or to reduce portion sizes, resulting in lower energy intakes and increased levels of undernourishment and mineral/vitamin malnutrition (FAO 2008). In Sri Lanka, for example,

declining wages and large increases in the costs of basic necessities in 2008 forced migrant women workers who already spent a quarter of their wages on food to reduce their daily meals from three to two and to reduce the diversity of their diets (UN Women 2011).The increasing specter of worsening malnourishment amongst vulnerable populations may delay the attainment of the MDGs even further than is currently predicted.

Vegetables are not just food; they are also an important part of culture and national cuisines, and their lack can lead to social tension. The inability to obtain key vegetables that are vital to ethnic cuisines, such as onions in India or West Africa or chili peppers in Indonesia, may spark urban civil protest and unrest. A six-fold increase in the price of onions in 1998 was one factor that contributed to the downfall of two state governments in India. A similar onion price rise in late 2010 and early 2011 was a significant contributor to inflationary stress on poor consumers, and exacerbated trade tensions with Pakistan as both countries sought to ensure sufficient supplies for their populations (Guha et al. 2010). Chili pepper prices in Indonesia rose ten-fold in early 2011 compared with previous years and they cost more than beef per kg in Jakarta (Firdaus 2011). The government urged citizens to grow their own chilies and handed out 100,000 seed packs (BBC 2011). There is thus some justification on 'security' grounds that adequate attention to agriculture and particularly horticultural research may be important levers in maintaining a peaceful environment in cities (McKay 2009; Wahlqvist et al. 2009; FAO 2008).

Global climatic uncertainty will further exacerbate underinvestment in vegetable research. It is increasingly important to help farmers become more resilient in the face of greater warming, cooling, drought, salinity, flooding, excessive humidity, high winds or combinations of these constraints. This research area receives comparatively little attention today. The world also urgently needs research programs to manage the likely increases in biotic stresses due to climate change. Pests and pathogens have been a continually evolving challenge and threat to the crops and livelihoods of poor farmers. Ongoing climate change may result in more stressed crops that are vulnerable to pest and disease attack. Likewise, pollinating agencies for plants such as bees *etc*. may also come under pressure which could be a further negative influence on crop productivity. Climatic changes also may drive selection pressure for more aggressive fungi, bacteria and viruses; breeding programs will be needed to monitor such trends and incorporate resistance traits where possible (de la Pena and Hughes 2007). Breeding as well as cultural techniques such as grafting, integrated pest management (IPM) and growing crops under protective covers, will have to be further exploited to reduce farmer exposure to crop losses. Farmers must be better prepared to handle future climatically-induced production uncertainties. If not, supply uncertainties and price rises inevitably will be exacerbated (Keatinge et al. 2009; AVRDC 2010).

Many vegetable crops such as African green leafy vegetables have received only a very small amount of research attention, so the expected financial rate of return and rapid research payoffs would be many, many times better than the incremental gains one today might expect from a further additional investment in staple cereals research. Nevertheless, this paper does not seek to undermine agricultural research in staple cereals, which are vital components of our diets, but rather to redress the current imbalance in investment and thus achieve a better overall efficiency in food production to ensure that varied and nutritious diets can be a reality for all people.

How can the poor be helped to access and afford vegetables—and thus contribute to their food and nutritional security?

The answer to this question is very simple: where possible, they grow their own. One of the major advantages of vegetable production is that a large amount can be produced in a short time from a small area compared to field crops such as the staple cereals. Although some of the world's poor people are completely landless, many people living on incomes of less than one US dollar a day still can have access to productive plots of land, which could be as small as 6×6 m. Even in urban and peri-urban environments access to (rather than formal ownership of) such a small piece of land over a 6-month period is more easily attained than perhaps is imagined. On this basis, home gardens and/or allotments can be readily developed as a proven means of overcoming malnutrition.

For example, research with poor tribal populations in northeast India has shown that the provision of a well-planned home garden nutrition seed pack including about two dozen vegetable species can make a major difference in improving the nutrition of a family of four. An area of only 6×6 m is needed, and production can be sustained if home gardeners save the seed of open- or self-pollinated lines for future planting. Research by AVRDC has found that three-quarters of vegetables produced in home gardens are consumed by the family. The high diversity of vegetables provided means that intensive crop rotations are possible, new vegetables are being added to diets, and the annual production of 250–300 kg of vegetables from small garden plots provides largely sufficient vitamin A and C for the whole family (Table 3). Large-scale work on home gardens in Bangladesh that began in the 1990s found that the sale of excess vegetables from home gardens also had nutritional benefits, as the money was used to buy extra rice and other food needs (Bushamuka et al.

2005). Helen Keller International has found that the nutrition and prosperity of villages that have adopted this type of homestead gardening along with the raising of smallstock are substantially better than neighbouring control villages (Talukder et al. 2010). Such technologies are easily scalable and transferable to many other locations where people are suffering malnutrition.

It is necessary to carefully select the home garden crop mixture for environmental suitability and to meet local cultural practices and tastes. A crop calendar ensures varied and nutritious vegetable supply for the full extent of the available growing season. Hardy lines are needed that can cope with local pest constraints as common control measures such as pesticide spraying will be unavailable to poor growers. Opportunities also exist for preservation of vegetables through solar drying or other storage methods. These are important areas in which training and extension can benefit poor and often illiterate home gardeners. The same issues apply to agronomic, production and harvesting considerations. Advice on suitable cooking methods and recipes to make vegetable dishes tasty, satisfying and nutritious all require careful research and local adaptation to existing cultural conditions.

In South Asia and sub-Saharan Africa where the majority of the world's poor are found, the main people responsible for growing home gardens and household food preparation are female. Improving their skills in home gardening and food preparation from garden produce makes a major, if often unstated, contribution to the empowerment of women, household decision-making and thus the potential attainment of MDG 3 (Promote gender equity and empower women; Bushamuka et al. 2005).

Multi-species seed packs selected for nutritional qualities, adaptability, and phytosanitary acceptance have proven to be of value in helping families recover more quickly from natural disasters, as the first food can reach the table within a month after sowing such as leafy crucifers e.g. kale (*Brassica oleracea*) and pakchoi (*B. campestris*), and other green leafy vegetables such as amaranth (*Amaranthus* spp.) and kang-kong (*Ipomoea aquatica)*. The role of good local partners is vital in this regard, as they provide distribution mechanisms and on-site demonstration and agronomic advice without which the seeds alone may be ineffective, even if instruction pamphlets in local languages are provided. AVRDC gleaned this experience from the distribution of seed packs through partner World Vision International in mountainous areas of Taiwan devastated by Typhoon Morakot (Tsou 2009; AVRDC 2009).

The critical importance of farmers using good agricultural practices in production to ensure the wholesomeness and nutritional value of vegetables

All the nutritional benefit associated with vegetables can be lost if the produce is contaminated by harmful micro-organisms, heavy metals or pesticides. It is important that growers adopt good agricultural production practices to minimize contamination from pesticide residue, bacteria, viruses or helminths hostile to humans, or from mycotoxins due to poor drying and storage. If farmers use inappropriate insecticides or overspray throughout the season, particularly close to harvest, then their produce may be seriously contaminated. Overspraying also may poison the farmer and his family unless appropriate safety measures are taken whilst spraying. Unfortunately, such precautions are seldom the norm. India accounts for one-third of all the world's pesticide poisoning cases (Indira Devi 2007) and vegetables

Table 3 Daily vegetable and nutrient availability of garden produce harvested from 6×6 m home garden models

	RDA[a]	Hyderabad[b] model		Punjab[c] model		Jharkhand[2] model	
		Daily availability	% RDA	Daily availability	% RDA	Daily availability	% RDA
Vegetables, g/d	750	831	111	449	60	537	72
Energy, kcal/d	8980	235	3	210	2	196	2
Protein, g/d	196	20	10	15	8	14	7
Vitamin A, μg RE/d	2400	2958	123	2231	93	1667	69
Vitamin C, mg/d	160	382	239	153	95	203	127
Folate, μg DFE/d	670	792	118	434	65	378	56
Iron, mg/d	81	13	16	7	9	7	9
Zinc, mg/d	41	5	12	2	6	4	9

[a] RDA: Values were the sum of RDA of 4 household members including one adult male and one adult woman both with moderate work, one child of 7–9 years old, and one 14–15 year-old girl. RDA data source: NIN (2010)

[b] On-station production (Central India)

[c] Farmers' field production (Northern India)

such as eggplant and cauliflower grown in south Asia often pose health hazards to farmers and consumers alike (Weinberger and Srinivasan 2009). IPM techniques and better understanding of crop management and the consequences of misuse of pesticides by the farming community are urgently needed if this difficult problem is to be effectively addressed.

The postharvest environment for vegetables is another potential source of contamination. For example, green leafy and salad vegetables are often grown in peri-urban environments with water contaminated with pollutants; if these products are then washed prior to market in unsanitary facilities, the result is an extremely unhealthy product for urban consumers. Research by the International Water Management Institute has shown that the effect of "grey" water irrigation sources can be considerably ameliorated if the product is at least washed in fresh water under sanitary conditions prior to marketing (Hope et al. 2008; Amoah et al. 2011).

A further example of unsound postharvest practices is found in chili peppers. Improper drying of chilies encourages the growth of the fungus *Aspergillus flavus* and substantial aflatoxin contamination of dried chili peppers is common. Surveys from the largest dry chili market in the world at Guntur (Andhra Pradesh State, India) have shown that a significant number of samples of various grades and powders of chili may considerably exceed the Indian Government's maximum permissible aflatoxin presence rate of 10 micrograms per kilogram. Such rates are extremely detrimental to consumer health (Reddy et al. 2002) but care and understanding of the concerns can minimize the contamination.

A high proportion of vegetables are lost between field and fork, largely because postharvest areas of vegetable research are neglected by the scientific community particularly for developing countries and for local consumption. In the last decade, only about 10% of agricultural research funds were available for postharvest research studies (Rolle 2006).

Conclusions

Merely feeding the world on cereals or other carbohydrate-rich staples alone—the present emphasis on food security—is not enough. We must ensure that people are not only fed, but also adequately nourished. The new watchwords of "food and nutritional security" in the title of this paper should enter the vocabulary of politicians everywhere. This will prompt their donor agencies to view overcoming malnutrition as the globally critical and immediate concern which it deserves to be. Greater crop diversity with a focus on nutrient-dense vegetables and pulses must be encouraged, with good agricultural practices for farmers, and the promotion of home gardening and small horticultural enterprises for the poor. These actions would bring more certain and faster progress toward attaining Millennium Development Goals 1, 3, 4, 5, 6 and 7, and help abolish the scourge of malnutrition.

The present trends of global climatic uncertainty exacerbate the need for a strong vegetable research and development sector. We should not forget that late blight (*Phytophthora infestans*)—the instigator of the Irish potato famine that devastated the poor in Europe in the nineteenth century—continues to this day as one of the most serious diseases of not only of potato but of all other *Solanaceous* crops, including many important vegetables such as tomato, peppers and eggplant. If a further global pandemic were to occur in the near future, it is uncertain whether the global intellectual and research resources in horticulture exist to prevent it getting seriously out of hand. The time to act is now!

References

Aguilar, A. V. J. (2005). *Rice in the Filipino diet and culture*. Discussion Paper Series No. 2005–15, Manila: Philippines Institute of Development Studies.

Asian Development Bank (ADB). (2006). *Final project report for RETA 6067*. Manila: ADB.

Amoah, P., Keraita, B., Akple, M. S. K., Drechsel, P., Abaidoo, R. C., & Konradsen, F. (2011). *Low cost options for health risk reduction where crops are irrigated with polluted water in West Africa*. IWMI Research Report 141, Colombo, Sri Lanka: IMWI http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/PUB141/RR141.pdf.

AVRDC. (2009). Seeds for new growth. *AVRDC newsletter 30th November 2009*, Shanhua, Taiwan: AVRDC. http://www.avrdc.org/press/2009/AVRDC_World%20Vision_press%20release_30Nov09.pdf.

AVRDC. (2010). *Prosperity for the poor and health for all: Strategic Plan 2011–2025* (p. 41). Shanhua: AVRDC.

AVRDC. (2011). *Medium-term Plan 2011–2013* (p. 88). Shanhua: AVRDC.

Bailey, L. B. (2000). New standard for dietary folate intake in pregnant women. *American Journal of Clinical Nutrition, 71*, 1304S–1307S.

BBC. (2011). Indonesians urged to grow chillies to combat price rise. *BBC news Asia Pacific* 6th January 2011.

Belot, M. & James, J. (2009). Healthy school meals and educational outcomes. *ISER Working Paper Series*, Institute for Social & Economic Research, Colchester, Essex, UK.

Brown, J. L., & Pollitt, E. (1996). Malnutrition, poverty and intellectual development. *Scientific American, 274*, 38–43.

Bushamuka, V. N., de Pee, S., Talukder, A., Kiess, L., Panagides, D., Taher, A., et al. (2005). Impact of a homestead gardening program on household food security and empowerment of women in Bangladesh. *Food and Nutrition Bulletin, 26*, 17–23.

Cambodia Development Research Institute. (2008). Impact of high food prices in Cambodia. http://home.wfp.org/stellent/groups/public/documents/ena/wfp189739.pdf.

Davis, D. R., & Riordan, H. D. (2004). Changes in USDA food composition data for 43 garden crops, 1950–1999. *Journal of the American College of Nutrition, 23*, 669–682.

de la Pena, R., & Hughes, Jd' A. (2007). Improving vegetable productivity in a variable and changing climate. *Journal of Semi-Arid Tropical Agricultural Research, 4*, 22.

Department of Agriculture. (2011). *Administrative Order Series 2011 No. 15*. Republic of the Philippines, Quezon City, Philippines. http://www.da.gov.ph/n_agrilaws/AO2011/ao15.pdf.

De Pee, S., & Bloem, M. W. (2007). The bioavailability of (pro) vitamin A carotenoids and maximizing the contribution of homestead food production to combating vitamin A deficiency. *International Journal for Vitamin and Nutrition Research, 77*, 182–192.

Dixon, J., Braun, H.-J., Kosina, P., & Crouch, J. (2009). *World wheat facts and futures* (p. 95). Mexico City: CIMMYT.

FAO/WHO. (2004) *Vitamin and mineral requirements in human nutrition: Report of a joint FAO/WHO expert consultation, Bangkok*, Thailand, 21–30 September 1998. ftp://ftp.fao.org/docrep/fao/004/y2809e/y2809e00.pdf. (Accessed in 2009).

FAO. (2008) *The state of food insecurity in the world 2008*. ftp://ftp.fao.org/docrep/fao/011/i0291e/i0291e00.pdf. (Accessed in August 2011).

FAO. (2009). *FAOSTAT on-line*. Rome: United Nations Food and Agriculture Organization. http://faostat.fao.org/default.aspx. (Accessed in 2010).

FAOSTAT. (2010) *Food supply: Crops primary equivalent: Food supply quantity 2007 (g/capita/day)*. http://faostat.fao.org/site/609/default.aspx#ancor. (Accessed in August 2010).

Firdaus, I. (2011). Indonesians fired up by the soaring price of chili pepper. *China Post*, February 11th, 2011.

Food and Nutrition Research Institute, Department of Science and Technology of the Government of the Philippines. (2008). *Overview of the 7th National Nutrition Survey* (p. 11). Manila: Government of the Philippines.

Glewwe, P., & King, E. M. (2001). The impact of early childhood nutritional status on cognitive development: Does the timing of malnutrition matter? *World Bank Economic Review, 15*, 81–113.

Guha, R., Gangopadhyay, A. & Sahni, D (2010) Onion price surge roils India. *Wall Street Journal, Dec, 22,* http://online.wsj.com/article/SB10001424052748704851204576034721326617418.html. Accessed 7 Sept. 2011.

Hanson, P. M., Yang, R.-Y., Wu, J., Chen, J.-T., Ledesma, D., & Tsou, S. C. S. (2004). Variation for antioxidant activity and anti oxidants in tomato. *Journal of the American Horticultural Science Society, 129*, 704–711.

Harvest Plus. (2010). Statement on the potential benefits of bioforticiation on the nutritional status of populations. http://www.harvestplus.org/sites/default/files/HarvestPlus_statement_benefits_of_biofortification_8-17-10.pdf. (Accessed in 2011).

Heaver, R. A., & Hunt, J. M. (1995). *Improving early childhood development: An integrated program for the Philippines* (p. 174). Washington: World Bank.

Hogan, P., Dall, T., & Nikolov, P. (2003). Economic costs of diabetes in the US in 2002. *Diabetes Care, 26*, 917–932.

Hope, L., Keraita, B., & Akple, M. S. K. (2008). Washing of vegetables grown in urban farms in irrigation water in Kumasi, Ghana. *Urban Agriculture Magazine Vol, 20*, 29–30. http://www.ruaf.org/sites/default/files/UAM%2020%20-%20pagina%2029-30.pdf.

Indira Devi, P. (2007). *Pesticide use in the rice bowl of Kerala: Health costs and policy options*. SANDEE working paper No. 20–07, p.40. http://www.sandeeonline.org/uploads/documents/publication/764_PUB_workingpaper_20_indira.pdf.

International Diabetes Federation. (2009). *Diabetes Atlas* (4th ed.). Brussels: IDF.

Keatinge, J. D. H., Ledesma, D., Hughes, J. d'A., & de la Pena, R. (2009). *A strategic look to the future for vegetable research: The World Vegetable Center and its partners. Global Climate Change: Imperatives for Agricultural Research in Asia-Pacific* (pp. 113–119). Tsukuba: JIRCAS.

Keatinge, J. D. H., Waliyar, F., Jamnadass, R. H., Moustafa, A., Andrade, M., Drechsel, P., et al. (2010). Re-learning old lessons for the future of food: By bread alone no longer—diversifying diets with fruit and vegetables. *Crop Science, 50*, 51–62.

Koebnick, C., Heins, U. A., Hoffmann, I., Dagnelie, P. C., & Leitzmann, C. (2001). Folate status during pregnancy in women is improved by long-term high vegetable intake compared with the average western diet. *Journal of Nutrition, 131*, 733–739.

Mayer-Foulkes, D. A. (2011). A survey of macro damages from non-communicable diseases: Another challenge for global governance. *Global Economy Journal, 11*, 1–26.

McKay, J. (2009). Food and health considerations in Asia-Pacific regional security. *Asia Pacific Journal of Clinical Nutrition, 18*, 654–663.

Midmore, D.J., Ninez, V. & Venkataraman, R. (1991) *Household gardening projects in Asia: Past experience and future directions*. Technical Bulletin No. 19, Shanhua, Taiwan: AVRDC pp 28.

Naico, A. T. A., & Lusk, J. L. (2010). The value of a nutritionally enhanced staple crop: Results from a choice experiment conducted with orange-flesh sweet potatoes in Mozambique. *Journal of African Economies, 19*, 536–558.

NIN. (2010). *National Institute of Nutrition: Nutrient Requirements and Recommended Dietary Allowances for Indians: A report of the expert group of the Indian Council of Medical Research 2009, RDA 2010 draft document*. Hyderabad: Indian Council of Medical Research.

Northstone, K., Joinson, C., Emmett, P., Ness, A. & Paus, T. (2011). Are dietary patterns in childhood associated with IQ at 8 years of age? A population-based cohort study. *Journal of Epidemiology & Community Health*, Published Online First: 7 February 2011; doi:10.1136/jech.2010.111955.

OMG. (2011). *Oh my gulay!* http://www.ohmygulay.prg/omg/beta (Accessed in September 2011).

Popkin, B. (2007). The world is fat. *Scientific American, 297*, 88–95.

Reddy, D. V. R., Thirumala-Devi, K., Reddy, S. V., Waliyar, F., Mayo, M. A., Rama Devi, K., et al. (2002). Estimation of aflatoxin levels in selected foods and feeds in India. In E. Hanak, E. Boutrif, P. Fabre, & M. Pineiro (Eds.), *Food safety management in developing countries* (pp. 1–4). Montpellier: CIRAD-FAO.

Rolle, R. S. (2006). *Post harvest management of fruit and vegetables in the Asia Pacific Region* (p. 307). Rome: FAO.

Ruel, M. T. (2003). Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities. *Journal of Nutrition, 133*, 3911S–3926S.

Talukder, A., Haselow, N. J., Osei, A. K., Villate, E., Reario, D., Kroeun, H., SokHoing, L., Uddin, A., Dhunge, S., & Quinn, V. (2010). Homestead food production model contributes to improved household food security and nutrition status of young children and women in poor populations—lessons learned from scaling-up programs in Asia (Bangladesh, Cambodia, Nepal and Philippines). *Field Actions Science Reports* [Online], Special Issue 1. http://factsreports.revues.org/404 . (Accessed 2011).

Tsou, T.-T. (2009). With seed donations from AVRDC, farmers can begin sowing again. *China Times* 1/12/2009, Taipei, Taiwan: China Times (in Mandarin).

UN Women. (2011). *Facts & figures on women, poverty & economics*. http://www.unifem.org/gender_issues/women_poverty_economics/facts_figures.php. (Accessed in August 2011).

USDA. (2010). *USDA National Nutrient Database for Standard Reference, Release 23*. U.S. Department of Agriculture, Agricultural Research Service. Nutrient Data Laboratory Home Page, http://www.ars.usda.gov/nutrientdata. (Accessed in August 2010).

Vijayalakshi, P. S., Amirthaveni, S., Devadas, R. P., Weinberger, K., Tsou, S. C. S., & Shangmugasunduram, S. (2003). *Enhanced bioavailability of iron and mungbeans and its effects on health of schoolchildren*. Technical Bulletin 30, Shanhua, Taiwan: AVRDC.

Wahlqvist, M. L., Keatinge, J. D. H., Butler, C. D., Friel, S., McKay, J., Easdown, W., et al. (2009). A Food in Health Security (FIHS) platform in the Asia-Pacific Region: The Way Forward. *Asia Pacific Journal of Clinical Nutrition, 18*, 688–702.

Weinberger, K., & Srinivasan, R. (2009). Farmers' management of cabbage and cauliflower pests in India and their approaches to crop protection. *Journal of Asia Pacific Entomology, 12*, 253–259.

WHO. (2010a) *Global health observatory data repository: MDG 4: Child mortality, under-five mortality rate*. http://apps.who.int/ghodata/. (Accessed in August 2010).

WHO. (2010b) *Global health observatory data repository: MDG 1: Poverty and hunger, Children aged <5 years underweight*. http://apps.who.int/ghodata/. (Accessed in August 2010).

WHO. (2010c). *Indicators to monitor the implementation of the comprehensive implementation plan*. http://www.who.int/nutrition/EB128_18_backgroundpaper4_nutrition_indicators.pdf. (Accessed September 2011).

Yach, D., Stuckler, D., & Brownnell, K. D. (2006). Epidemiologic and economic consequences of the global epidemics of obesity and diabetes. *Nature Medicine, 12*, 62–66.

Yang, R.-Y., Hanson, P. M., & Lumpkin, T. A. (2007). Better health through horticulture—AVRDC's approach to improved nutrition of the poor. *Acta Horticulturae, 744*, 71–77.

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