Vegetables Go to School: Improving Nutrition by Agricultural Diversification

Training of Trainers Manual

August 2013

Prepared by

Swiss TPH
Swiss Tropical and Public Health Institute
Schweizerisches Tropen- und Public Health-Institut
Institut Tropical et de Santé Publique Suisse

Associated Institute of the University of Basel

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Swiss Agency for Development and Cooperation SDC

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1 Introduction

Malnutrition is one of the most serious health problems in the world, with enormous human and economic costs. It includes insufficient intake of carbohydrates, fats and protein, micronutrient deficiencies, as well as excessive intake of calories through imbalanced consumption of fats and sugars. To address this problem, aspects of education, health, nutrition and agriculture/horticulture need to be addressed in a coordinated way to change the behavior of individuals, communities and populations. Schools are an ideal entry point for such multi-facet interventions, as education can tackle the linked issues of agriculture/horticulture, health and nutrition in such a way as to induce long-term behavioral change.

The goal of the Vegetables Go to School project is to contribute to improved nutritional security in the target countries (Burkina Faso, Tanzania, Bhutan, Nepal, Indonesia and the Philippines) through school vegetable gardens linked to other school-based health, nutrition and environmental initiatives with close participation of local communities.

The project has three phases:

- Phase I (2012/2013-2015) aims to build institutional capacity to implement school gardens in a sustainable way, to design school vegetable gardens adapted to local conditions using country-specific nutritious and easy to grow vegetables with targeted cropping schedules, crop management technologies and protocols for ensuring seed supply. The phase also aims to provide scientifically sound evidence that school vegetable garden-based approaches actually improve nutrition among school children.
- Phase II (2016-2018) aims to scale-out the implementation of school vegetable gardens in target countries to make a larger impact on the ground.
- Phase III (2019-2020) aims to institutionalize the project to ensure long-term sustainability after the international project team withdraws from the project.

Building institutional capacity, designing locally adapted school gardens, and collecting data following scientific standards are time consuming activities in Phase I; the target number of school vegetable gardens to be established in Phase I is therefore limited to 20 schools, although country teams can decide to increase this number if they can manage with their available resources. The research component is, however, an essential part of the project as there is only limited scientific evidence on the impact of school gardens in developing countries at present. We expect that being able to show this impact will create important opportunities to raise additional project resources for the scaling-out of school vegetable gardens in phase II.

The objective of this project implementation manual is to support the participants at the Training-of-Trainers workshop to be held at AVRDC headquarters in Taiwan from 18 August to

13 September 2013. The aim of this workshop is to develop country-specific school vegetable garden action plans that specify how the country teams plan to implement the project. The manual does not give detailed guidelines on how to implement a school garden but provides general principles that set the framework for a successful project implementation. It is noted that the project is implemented in a decentralized fashion in which so-called country teams led by an AVRDC appointed country manager (for Burkina Faso, Nepal and Tanzania) implement the project locally. The terms of reference for the country team and country manager are included in Annex 1.

2 School Vegetable Garden Design and Realization

Gregory C. Luther, Ramasamy Srinivasan, Li-Ju Lin and Wuu-Yang Chen

AVRDC-The World Vegetable Center

20-21 August, 26, 29 August and 6 September

2.1 Site and vegetable crop selection for the school garden

2.1.1 Site selection

Choose an open area (fairly level ground) that will allow the plants to receive full sunlight (not shaded) at least half of the day. If possible, choose land with healthy soil and good drainage, with easy access to an unpolluted water source for irrigation, away from potential contamination sources such as garbage. The garden can be in the back, front or side of the school, away from main traffic routes if possible and visible from/or near classrooms, depending upon space availability.

2.1.2 Size of the school garden

The size of a school garden depends on the available land/space and number of students involved. Children must be able to reach every part of the beds easily without standing on the soil. The suggested size per plot is 0.6-1 m wide and 1-1.5 m long, with 1 m wide paths to allow the wheelbarrow and children to pass. The plot length can be expanded depending on the space availability and planting plan. If space is limited, vegetables can be planted in containers such as pots, cans, boxes, poly bags or any locally-available materials.

2.1.3 Selection of vegetables

Choosing what vegetables to grow involves many considerations. Below are some issues which should be considered to decide what to grow in the school garden:

- Select vegetables that are preferred and likely to be eaten in local diets
- Select a variety of vegetables with nutritional diversity
- Select vegetables that are hardy, easy to grow and manage, and well adapted to the local climate and soil
- Select vegetables that produce good yields and are tolerant to common pests and diseases
- Select vegetables that fit into the school schedule and can be harvested before the end of

the semester

2.2 Planning your planting schedule

2.2.1 Crop rotation- a key to successful gardening

Crop rotation is the practice of growing different crops in succession on the same land. It is commonly used to control diseases and insect pests in the vegetable garden, and to build up the organic matter and soil nutrients that certain plants use during their life cycle. Different plants take different nutrients out of the soil and add back other elements or enhance the soil in other ways. Therefore, to prevent your garden from becoming less productive from season to season, crop rotation is highly recommended. Rotating your crops in this manner helps to keep your soil makeup balanced, pests and diseases at a minimum level and your garden healthy.

How to plan a rotation

1. Prepare a list of vegetables to be planted in the garden.
   Divide the vegetables into four groups based on what part of the plant you plan to eat, i.e., plants grown for **leaves or flowers** (such as amaranth, lettuce, broccoli, cabbage), **fruits** (such as tomato, eggplant, pepper, cucumber), **roots** (such as carrot, radish, onion) and **legumes** (such as beans, peas, cover plants/green manure like alfalfa or clover).
2. Group the plants together in botanical families.
   This is to help you understand what crops are closely-related. In general, crops in the same family should not be planted in the same field continuously.
3. Draw a map of the growing area and divide it into equal sections.
4. Work out which crops will be planted in which area.
5. Keep records of what actually happens, not just what you planned.
6. Use this information when planning for next year.

How long should the rotation last?

- The longer the better
- Normal length is 4 years; if not possible, at least 2 years

Sample crop rotation plan:

	Plot 1	Plot 2	Plot 3	Plot 4
Year 1	Legumes	Leaves/flowers	Fruits	Roots
Year 2	Leaves/flowers	Fruits	Roots	Legumes
Year 3	Fruits	Roots	Legumes	Leaves/flowers
Year 4	Roots	Legumes	Leaves/flowers	Fruits

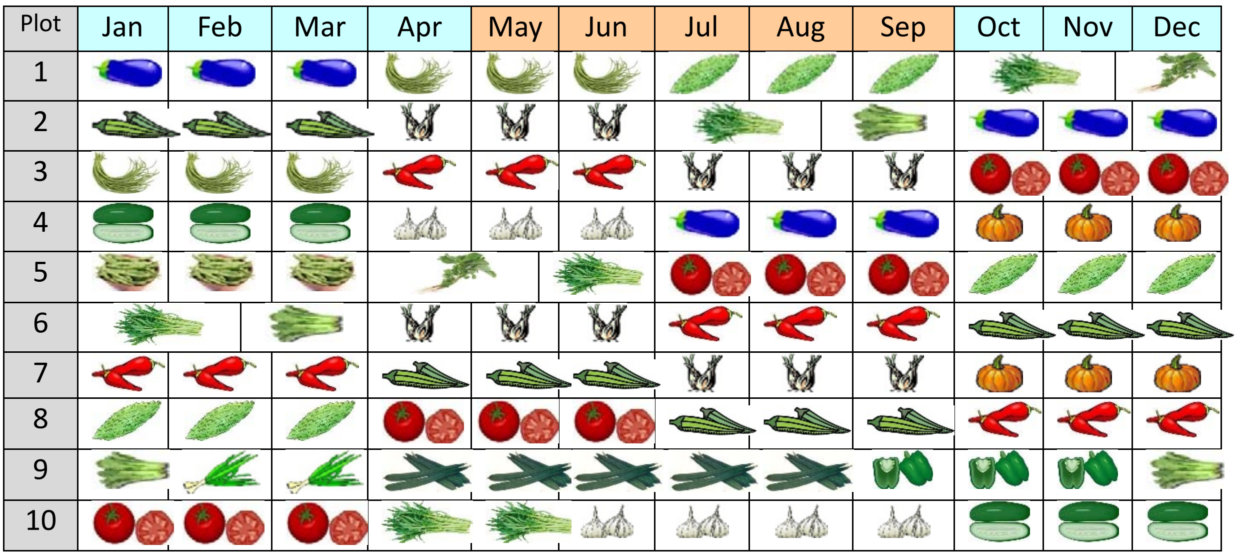
Plant leaf/flower crops to the plot where legumes were planted last year, because legumes fix nitrogen in the soil, and leaf plants need large amounts of nitrogen. The fruits follow the leaf plants because they need phosphorus, and not too much nitrogen. The roots follow the fruits because they need potassium and need nitrogen less than the fruits. Finally, the legumes follow the roots to put nitrogen back into the soil.

2.2.2 Set up a planting plan

To maximize utilization of limited space and assure year-round production through crop rotation, set up a planting schedule for school garden is needed. Prepare a planting calendar of all the vegetables you plan to grow in the garden by following the table below and mark the suitable growth period in colors:

Crop name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tomato												
Kangkong												
...												

Based on the information from the planting calendar and vegetable groups for rotation, a year-round planting schedule can be set up. Below is an example for a pilot school garden in East Java, Indonesia.



Rainy season Dry season

2.3 Healthy seedling preparation

You can raise seedlings directly on raised beds, or use locally-available seedling boxes, trays (wooden or plastic), plastic bags/pots, other similar types of containers (such as rolled banana leaves) or devices with drainage holes on the bottom.

2.3.1 Raising seedlings

Seedbed method

1. Prepare the raised beds and improve the soil condition by applying compost or organic fertilizers. Compost should be fully mature.
2. Sterilize the beds by burning straw on soil surface or exposing under the sun for three weeks to minimize levels of soil-borne pathogens, such as bacteria, fungi, nematodes and insect pests.
3. Sow seeds directly to the beds and cover the seeds with a thin layer of soil.
4. Cover the beds with rice straw.
5. Use simple structures or materials (such as 50-mesh nylon netting or any locally-available shading net) to protect seedlings against rain, sun and insects.
6. After sowing, water the beds using a fine sprinkler immediately.
7. Keep 5 cm between seedlings and thin out excess ones when first true (non-cotyledon) leaves have appeared.

Seedbox or tray method

1. Use a growth medium that drains well, such as peat moss, commercial potting soil, or a mixture of soil, compost, sand and rice hulls with a ratio of 1:1:1:1, or decomposed coco dust, soil and cow dung with a ratio of 2:1:1.
2. Sterilize the potting mixtures by exposing under the sun for three weeks or steam for 45 minutes.
3. Fill the seedling trays with medium and place the trays on raised areas such as benches or bricks under net tunnels or in the nethouse or covered by simple protecting structure.
4. Sow 1-2 seeds every 5 cm in the seedling boxes or trays and cover the seeds with a thin layer of potting mixtures.
5. After sowing, water the seedbox or trays with fine sprinkler or watering can immediately.
6. Thin out excess seedlings when first true leaves have appeared.

Seedling container method

Raising seedlings in separate pots, containers or plastic plug trays can minimize the root injury while transplanting and ensure higher survival rate in the field.

1. Fill the containers with sterilized potting mixtures mentioned in Seedbox or tray method.
2. Sow 1-2 seeds in one container and cover the seeds with a thin layer of potting mixtures.

3. Water the containers with a fine sprinkler or watering can right after sowing.
4. Thin out excess seedlings when first true leaves have appeared.

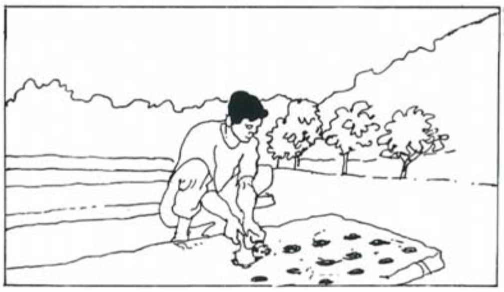
2.3.2 Seedling management

1. Watering: water daily (morning hours preferred) based on the local temperature and moisture.
2. Fertilization: if the leaves turn slightly yellow or seedlings seem thin at the two-leaf stage, irrigate the seedlings 1-2 times with a 0.5% ammonium sulfate solution (5 g ammonium sulfate dissolved in 1 liter of water), or 0.25% urea solution (2.5 g urea dissolved in 1 liter of water), or 0.1% commercial or locally-available NPK soluble fertilizers. Do not over-apply nitrogen or the seedlings will grow tall and thin.
3. Hardening: slightly reduce watering and expose seedlings to direct sunlight 1-2 weeks before transplanting. Thoroughly water the seedlings about 12 hours before transplanting to the field.
4. Transplanting: after 3-5 weeks (around 4 or 5-leaf stage), seedlings are ready for transplanting. Select vigorous and stocky seedlings to be transplanted in the garden.

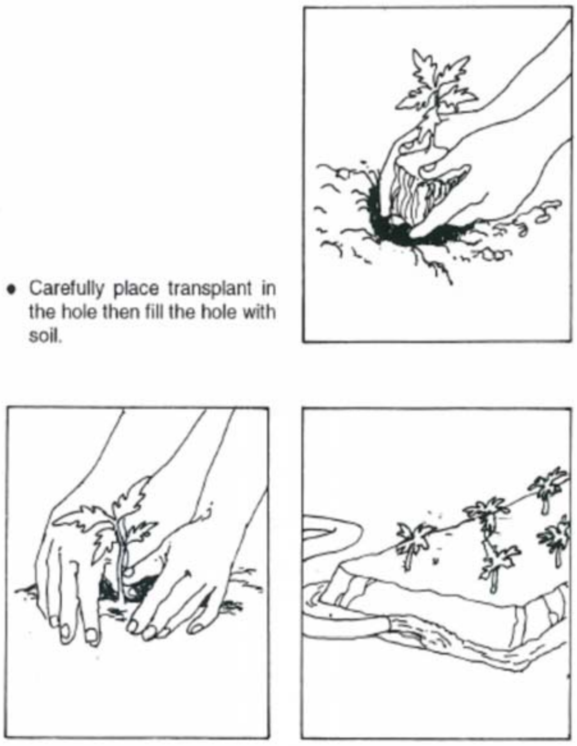
2.4 Integrated crop management

2.4.1 Transplanting

- Prepare land properly, and dig holes in rows following recommended spacing.



- Transplant in the afternoon during sunny days.
- How to transplant



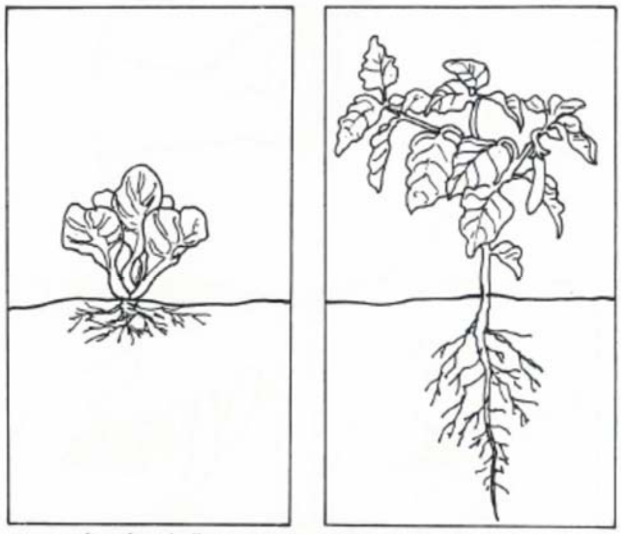
- Carefully place transplant in the hole then fill the hole with soil.
- Gently press downward to assure contact of roots with the soil.
- Irrigate newly transplanted seedlings.

2.4.2 Irrigation

- Methods of watering plants
  - Flood the bed – in dry places make a sunken bed to keep the water in.
  - Drip irrigation – use a drip hose or soaker hose.
  - Water by hand with a watering can or a plastic bottle with holes.
  - Make water traps – for example, keep the water in by digging a shallow trough round the plant.
  - Water plants individually with sunken tins or upended bottles.
- Amount and frequency of watering

Depends on:

- Root type



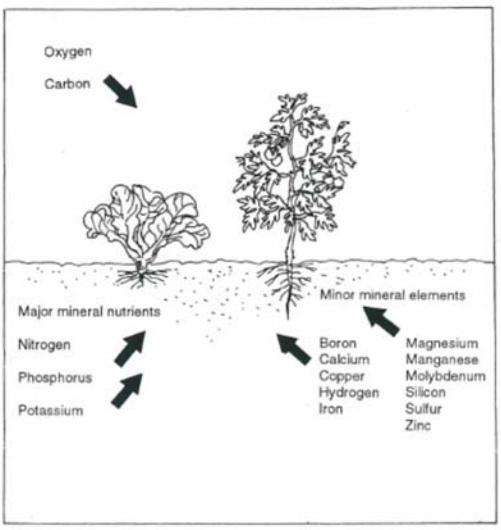
▲ more often for shallow-rooted crops like pechay, cabbage, mustard, and kangkong

▲ less frequent for deep-rooted crops like okra, tomato, eggplant, and pepper

2.5 Soil health and soil fertility management

Vegetables need nutrients, they are:

- Carbon and oxygen from the air, hydrogen from water, and mineral nutrients from the soil.
- Major nutrients (nitrogen, phosphorus, and potassium) in large amounts.
- Minor nutrients in small amounts.

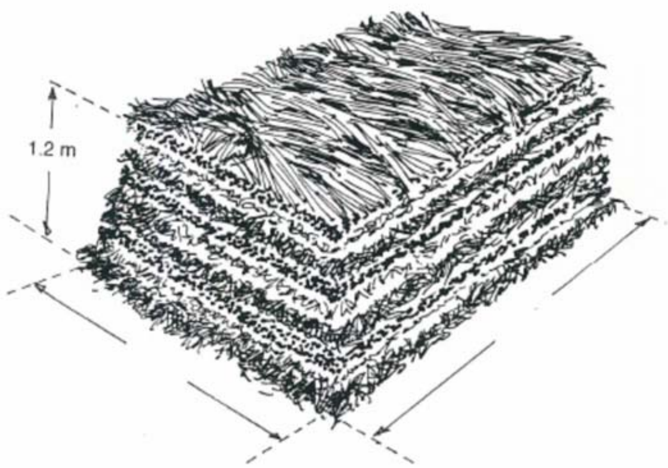


2.5.1 Starter Solution Technology (SST)

- Small amounts of very concentrated inorganic fertilizer solution (Starter solution, ST) are applied in a small volume of 50 ml to soils in the root vicinity immediately after transplanting, which build up high nutrient gradients in soil solution, provide young plants with readily available nutrients before their root systems are well established, thus enhancing the plant's initial growth significantly.
- After nutrient ions adsorbed on soil particles, the remaining nutrients in soil solution are directly available to the plants
- Time for application
  - At transplanting (roots are not accessible to nutrients)
  - During root injury (after disaster or heavy rain, diseases)
  - At fruit setting or heading stage (productive stage)
- Effects of starter solution
  - Enhance the initial growth of vegetables significantly
  - Reduce fertilizer amounts
  - Increase yield/fertilizer efficiency
  - Shorten growth duration
  - Enhance flower initiation
  - Decrease nutrient residues in soil, reduce environmental pollution
- How to apply Starter Solution?
  - Step 1: Apply manures and inorganic basal fertilizers in central band of beds or beside each plant.
  - Step 2: Transplant seedlings when soil is dry.
  - Step 3: Apply 50 ml concentrated Starter Solution near root vicinity in between plants and basal fertilizers immediately after transplanting.
  - Step 4: Follow by furrow irrigation (80% full), allow water moving upward to sustain the nutrients near root zones. If furrow irrigation is not available, let starter solution be adsorbed on soil particle surfaces, stand at least 30 minutes after application. Then, irrigate plants from other side of the plants using watering can.

2.5.2 Composting

- What is compost?
  - Compost is a form of organic matter and can be made from a range of organic materials usually considered to be waste.
  - Ingredients: straw, cut grass, organic waste from the kitchen, weeds, plants, leaves, animal manure (except from dogs and cats), wood ash, animal and fish bones, feathers, cotton cloth, bits of leather or paper, soil.
  - Do not use cooked food, large pieces of wood, plastic, metal, glass, crockery, wire, nylon, synthetic fabrics, coal ash, seeding grass or very tough weeds.
  - Composting is a natural process that involves the decomposition of organic matter. Millions of microorganisms drive the compost process by breaking organic matter down to its original nutrient form.
  - Highly beneficial to soil and plant growth.



- How to make compost?
  - Step 1: Collect all waste materials.
  - Step 2: Choose a shady level area measuring 3 meters long and 2 meters wide.
  - Step 3: Pile by layers the different compost materials.
  - Step 4: Water the pile evenly and avoid overwatering. Repeat Step 3 to make the pile higher.
  - Step 5: Test if the pile is hot inside by inserting a stick or thermometer all the way into the pile.

- Step 6: Turn the pile upside down when it has cooled down.
- After one month, the compost will be ready for use.

2.6 Integrated Pest Management

2.6.1 An introduction to Integrated Pest Management (IPM)

Pests are organisms that cause damage to things that are valued by human beings, such as agricultural crops. Pests can come in many forms, including insects, diseases, weeds, and mammals. Here we define agricultural pests as organisms that cause economic loss to crops. Limiting the damage that pests cause can be very important to farmers, particularly if the pest substantially reduces the harvestable yield.

Integrated Pest Management (IPM) is an approach which combines all useful methods for controlling a certain pest (or group of pests); optimally these methods will work synergistically. Integrating different IPM methods effectively requires skill and knowledge. The more we know about a pest's biology and ecology, the better we can manage the pest and minimize damage from it.

For our school gardens, IPM is recommended over broad-spectrum chemical pesticide use because these pesticides are harmful to human health and the environment. While most farmers worldwide rely primarily on chemical pesticides to control pests, it is hoped that our school gardens will be an inspiration for them to move towards IPM methods. In our project, IPM methods should be used for our school gardens and the home gardens that are generated from them.

A wide variety of methods are available in IPM, including biological control with natural enemies, bio-pesticides, pheromones, cultural control tactics, host plant resistance, mechanical/physical controls, autocidal controls and chemical controls. These are described in more detail in the introductory IPM presentation. More details can also be found in *Safer Tomato Production Techniques*, *Insect and Mite Pests on Eggplant,* the FAO School Garden Manual, and other references listed below.

Insect pests are one of the major groups of pests causing significant yield losses in vegetable crops. Sucking pests such as whiteflies, aphids, thrips and leafhoppers occur very early in the crop growth stages. They suck the plant sap (juice) from the growing shoots, leaves, flowers and pods or fruits. Whitefly feeding causes yellow spots and reduction in chlorophyll content. Aphid feeding causes leaf crinkling and stunting. Thrips feeding leads to the development of silvery scars, browning and drying of the leaves. Leafhopper causes yellowing, bronzing and drying (phytotoxemia), because of the injection of their toxic saliva while feeding. Whiteflies and aphids excrete a sticky substance (honey dew) that is rich in sugars and amino acids. Hence, honey dew favors the growth of a saprophytic fungus, sooty mould that covers the leaf surfaces and thus reducing the photosynthetic efficiency of the plants. In addition, whiteflies, aphids and thrips transmit the notorious plant viruses that cause curling, yellowing, wilting, etc in infected plants. Defoliators such as caterpillars and beetles sometimes cause serious threats by feeding most of the leaves. During the reproductive stages (flowering and fruiting)) of the vegetable crops, the borer pests are the major insects. They include flies, moths, butterflies, beetles and weevils. In dry and humid environment, mites and mealy bugs also become a major threat in the later growth stages of the vegetable crops. Although leaf miners attack the crop in seedling stages, they do not cause significant yield losses. The major vegetable pests are listed below:

Pest category	**Name**	**Major crops attacked**
Sucking pests	Whitefly (*Bemisia tabaci*)	tomato, eggplant, African eggplant, peppers, legumes, cucurbits, brassicas, okra
	Aphids (*Aphis gossypii*, *A. craccivora, Myzus persicae, Brevicoryne brassicae, Lipaphis erysiphe*)	tomato, eggplant, African eggplant, peppers, African nightshade, legumes, cucurbits, brassicas, okra, amaranth
	Thrips (*Thrips tabaci*, *T. palmi, Frankliniella occidentalis, Scirtothrips dorsalis, Megalurothrips* spp.)	tomato, eggplant, peppers, legumes, cucurbits, brassicas, onion
	Leafhopper (*Amrasca devastans*, *Empoasca* sp.)	eggplant, okra, legumes
	Spider mites (*Tetranychus* spp.)	tomato, eggplant, African eggplant, African nightshade, legumes, cucurbits, amaranth
	Broad mite (*Polyphagotarsonemus latus*)	peppers
	Mealy bugs (*Phenacoccus* spp., *Maconellicoccus hirsutus, Ferrisia virgata*)	tomato, eggplant, African eggplant, peppers, African nightshade, legumes, cucurbits, brassicas, okra, amaranth
Defoliators (leaf feeders)	Armyworms (*Spodoptera litura*, *S. exigua*)	tomato, peppers, legumes, brassicas, onion
	Spotted beetles (*Epilachna* spp.)	eggplant, bitter gourd
	Pumpkin beetles (*Aulacophora* spp.)	cucurbits
	Head caterpillar (*Crocidolomia binotalis*)	brassicas
	Leaf webber (*Hymenia recurvalis*, *Psara basalis*)	amaranth
	Pumpkin caterpillar (*Diaphania indica*)	cucurbits
Pod / fruit borers	Fruit borer (*Helicoverpa armigera*)	tomato, peppers, okra, legumes, brassicas

	Shoot and fruit borer (*Leucinodes orbonalis*)	eggplant
	Shoot and fruit borer (*Earias* spp.)	okra
	Pod borers (*Maruca vitrata, Etiella zinckenella, Lampides boeticus, Euchrysops cnejus*)	legumes
	Bean flies (*Ophiomyia* spp.)	legumes
	Diamondback moth (*Plutella xylostella*)	brassicas
	Web worm (*Hellula undalis*)	brassicas
	Fruit flies (*Bactrocera dorsalis, B. cucurbitae*)	tomato, peppers, cucurbits

In the sections of the manual below, we elaborate on several IPM methods that are easily available for school gardens.

2.6.2 Cultural practices

Clean cultivation is essential since weeds could act as the alternate hosts for the insect pests and the virus diseases transmitted by insects. Healthy seedling production practices should be followed to ward-off the early season sucking pests and the viruses that they transmit. Plants from the same family should not be planted next to each other, since they may share the common pests and diseases. Tall barrier crops such as corn, sorghum, sunn hemp or sugar cane could be planted around the garden to prevent the entry of insect pests.

2.6.3 Traps

Use of sex pheromone traps is recommended for tomato fruit borer, army worms, fruit flies, legume pod borers, eggplant and okra fruit and shoot borers, diamondback moth, and other pests for monitoring and/or mass-trapping. Yellow sticky traps could be used to monitor and trap whiteflies, leafhoppers, winged aphids, adult leaf miners, and other species. Blue sticky traps are recommended for managing thrips.

2.6.4 Biological control with natural enemies

Natural enemies attack and kill pests, thereby helping us control pests in a natural way. There are three main kinds of natural enemies:

1) ***Predators*** attack and feed on other animals (their “prey”); the prey are usually killed and eaten.
2) ***Parasitoids*** feed in or on other living animals for a relatively long time, consuming most or all of their tissues and eventually killing them.
3) ***Pathogens*** are microorganisms that cause diseases in pests, often killing the pests.

Natural enemies are usually present in our gardens and fields, as long as they have not been killed by toxic pesticides. Natural enemies are very sensitive to broad-spectrum chemical pesticides and are normally killed when a gardener treats his/her garden with these pesticides; this is one important reason to minimize chemical pesticide use.

Many people assume that all insects in their garden or field are pests that will harm their crops. However, only about 2% of the insect species worldwide are pests that cause economic damage. Many species of insects are natural enemies or other beneficial kinds of insects, such as decomposers which break down organic matter to make it useful to plants or pollinators which increase crop yields. Other insects feed on plants but do not cause economic damage.

To implement IPM, it is therefore very important to be able to differentiate between pests, natural enemies and other types of insects/organisms. We need to avoid misidentifying a natural enemy as a pest and killing it, which will make our pest control efforts more difficult. If we let natural enemies do their job, our job will be easier. We also need to know which organisms are actually pests, so that we can target our efforts towards managing them.

The presentation and activity in this ToT are designed to help you differentiate between pests, natural enemies and others, and especially be able to recognize natural enemies. There are some easily recognizable kinds or groups of natural enemies. These are:

- Dragonflies and damselflies (Order Odonata): all species are predators

- Praying mantises (Order Mantodea): all species are predators

- Lacewings and related insects (Order Neuroptera): many species are predators

- Wasps (Order Hymenoptera): many small wasps are parasitoids, while many large wasps are predators

- Earwigs (Order Dermaptera): many species are predators, while others are decomposers (also beneficial)

- Spiders (Order Araneae): all species are predators

Some other natural enemies are not as easy to distinguish from pests; for example, some kinds of beetles are natural enemies (predatory ladybird beetles) and others are pests (eggplant spotted beetles). It takes time to learn about the various kinds of natural enemies, but the effort is well worth it, since this knowledge allows us to manage pests in a more sophisticated manner (through IPM) and understand our agro-ecosystems better.

Predatory ladybird beetles, syrphid flies, lacewings, and other species are commonly present in gardens. These predators are highly effective against the soft bodied sucking insects and early stage caterpillars. Most of the sucking insects and borer pests have species–specific parasitoids that mostly keep the pest populations under check. However, use of broad-spectrum chemical pesticides should be avoided to encourage the proliferation of natural enemies in the gardens.

More photos of natural enemies can be found in the presentation and many of the references below, such as *Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia*.

2.6.5 Bio-pesticides

Bacillus thuringiensis (Bt) is a bacteria that causes diseases and mortality in most caterpillar (lepidopteran) pests. It can effectively curtail the damages caused by defoliators and borer pests. Nuclear polyhedrosis virus (NPV) is a viral pathogen that could also kill the insect pests. NPVs are commercially available for pests like tomato fruit borer and army worms. Entomopathogenic fungi are another group of pathogen that could control the sucking pests, defoliators and borer pests. They are also commercially available in several countries. Plant based pesticides such as neem and pyrethrum can be used against a wide range of pests. They reduce the feeding and egg laying by insects. Some organic salts can kill the soft bodied insects through desiccation. Mineral oils can be used to reduce the feeding by sucking insects and thus reducing the transmission of virus diseases.

2.6.6 Chemical pesticides

Chemical pesticides should be considered as the last resort in an integrated pest management strategy. Use of systemic pesticides and avoiding broad-spectrum pesticides could encourage the build-up of natural enemy populations. Safe pesticide application methods such as seed treatment, seedling treatment and spot application of pesticides are recommended. Pesticides having shorter waiting periods should be chosen to avoid the residue issues. Continuous use of pesticides belonging to the same mode of action group should be avoided to reduce the possible development of resistance. Only recommended pesticides should be used on the vegetable crops.

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3 Saving your own vegetable seeds

Andreas W. Ebert

AVRDC – The World Vegetable Center

Thursday 22 August

3.1 Introduction

Seed saving involves selecting suitable, healthy plants from which to save seeds, harvesting the fruits or pods at the right time, extracting, cleaning and drying the seed, packaging and storing them under proper conditions.

3.2 Pollination behavior of vegetable crops

Vegetable seeds can be saved from current production to sow new crops during subsequent season(s). To be able to do this successfully we need to know a little bit about the different ways of reproduction in vegetable crops. Many vegetable crops produce flowers with the male part (anther) and the female part (stigma) included in the same flower. These are called **perfect flowers**. Pollination occurs when pollen grains from anthers of the flower get into contact with the stigma. In many crops with perfect flowers self-pollination occurs. Vegetable crops like lettuce, tomato, and okra have the stigma so close to the anthers that the slightest wind movement of the plant can cause the pollen to drop on the stigma within the same flower, thus initiating the pollination and fruit-setting process. In peas and beans, self-pollination occurs even before the flower opens.

Highly self-pollinated crops are asparagus bean, also known as yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis*), cluster bean (*Cyamopsis tetragonoloba*), hyacinth bean (*Lablab purpureus*), French bean, also known as common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), garden pea (*Pisum sativum*), fenugreek (*Trigonella foenum-graecum*), lettuce (Lactuca satiuva), and tomato (*Solanum lycopersicum*). These vegetable crops are the easiest to save seeds as no special measures are required to maintain seeds pure.

Other vegetable crops with perfect flowers are **predominantly self-pollinated**, but cross-pollination may occur naturally to a certain degree. Among these crops are Lima bean (*Phaseolus lunatus*; cross-pollination 0.2-2.4%), eggplant (*Solanum melongena*; cross-pollination 0.7-15%); okra (*Abelmoschus esculentus*; cross-pollination 0-20%), hot and sweet pepper (*Capsicum annuum*; cross-pollination 5-40%). Increased fruit set and yield is often observed in these crops when cross-pollination is allowed to occur in open plantings.

Pre-dominantly cross-pollinated crops with perfect flowers. Some vegetable crops with perfect flowers are known to require cross-pollination. This entails external pollinators (bees, insects) to carry pollen from one flower to the stigma of the next flower. Onion (*Allium cepa*), cabbage (*Brassica* spp.), radish (*Raphanus sativus*), and carrot (*Daucus carota*) belong to this group. Reproduction and seed saving in these crops is a long and tedious process and requires two growing seasons.

Onion forms bulbs during the first year and this is followed by seed production in the second year. Seed-to-seed and bulb-to-seed methods are common in onion. The bulbs produced in the first year are either left in the field over winter to produce flowers in the second year or bulbs are lifted at the end of the first season, selected, cured and stored in a cool place for a minimum of two weeks at about 4 ^{o}C (refrigerator) and re-planted for flowering and seed production during the second season. An isolation distance of 500 meters between different cultivars is required to maintain seed purity.

***Brassica* crops** (broccoli, cabbage, mustard, turnip) follow a similar system and seed can be produced either by head-to-seed or seed-to-seed method. Tropical cultivars require little or no cold weather for flower induction and for these the seed-to-seed method can be applied. An isolation distance of 1000 meters between different cultivars is required to maintain seed purity.

Radish is related with *Brassica* crops. The biennial radish types from temperate climates require a cold period for flowering, while radishes of tropical origin produce flowers without an intermittent cold period. Both root-to-seed and seed-to-seed methods can be employed in radish seed production. The latter is preferred with cultivars that suffer from transplanting. An isolation distance of 1000 meters between different cultivars is required to maintain seed purity.

Carrot seed production also requires two seasons. Roots are formed during the first year and a low temperature stimulus (10 weeks below 15 ^{o}C) is required to induce flowering. Similarly to the aforementioned crops, seed-to-seed and root-to-seed methods can be used for seed production. As root rot is often high in the seed-to-seed method, transplanting of selected roots is usually preferred. An isolation distance of 800 meters between different cultivars is required to maintain seed purity.

Cross-pollinated crops with imperfect flowers. Other crops like maize and most varieties of the cucurbit family such as cucumbers, melons, pumpkins and bitter gourd have **imperfect flowers**, i.e. the anthers are found in male flowers and the stigma in female flowers on the same plant. Plants with imperfect flowers require either wind (maize) or insects (mostly bees) to transfer pollen from the male flowers to the stigma of the female flowers. Cucurbits are cross-pollinated by bees.

Nowadays, **commercial hybrid seed** is popular among vegetable growers. Hybrid seed is obtained by crossing two true-breeding (homozygous) parent plants by means of controlled pollination. Hybrid seed results in uniform, high-yielding plants. However, seeds from hybrid plants should not be saved as the off-spring will vary greatly from each other and yield is usually depressed. Some commercial hybrids may produce sterile seeds to avoid the re-use of the seeds.

3.3 Purity of seeds

Seed purity is not a major problem in highly self-pollinating crops, but could become an issue in predominantly self-pollinating crops with some natural outcrossing (lima bean, eggplant, okra, pepper). If **seed purity** is of high priority in these crops when saving seeds, then **bagging or caging** would be required as it is difficult to maintain a safe isolation distance of 100 meters for eggplant or 200 meters for okra and pepper between different varieties in relatively small school gardens. Such isolation distances are required for commercial, certified seed production to ensure that cross-pollination between different varieties planted at the same time at the same location does not take place.

Bagging. For the maintenance of school gardens only small amounts of seed are required. For this purpose, unopened flowers can be enclosed with a paper bag. In predominantly self-pollinating crops, hand pollination is not mandatory, but could improve fruit set and seed production, especially in eggplant, okra, and pepper. Cucurbit flowers (both male and female) can be bagged also, but in these crops hand pollination is mandatory.

Caging. Cages are often used for vegetable crops that flower over a long period of time. This will prevent insects from pollinating a given cultivar with pollen from a nearby growing different cultivar. Cages can be easily constructed with the help of bamboo sticks which are then covered with nylon mesh. As the cage will keep insects outside, hand-pollination in commonly cross-pollinated crops is required or bee hives need to be introduced inside the net cages.

Based on the described pollination behavior, highly and pre-dominantly self-pollinated vegetable crops are the best candidates for first experiments with saving your own seeds. Once this process is well mastered, one can move to saving seed from annual cross-pollinated crops and the very advanced level would be saving your own seed from strictly biennial crops like onion and carrot.

3.4 Orthodox seed development

Most vegetable crops produce seeds that can be dried to low seed moisture levels (to prolong storage life and viability) and can be stored at low temperatures. These are called orthodox seeds. The timing of seed collection is important since seed quality increases late in seed development – during the desiccation stage after the attainment of mass maturity, meaning after reaching maximum seed dry weight. The development of different seed quality attributes occurs sequentially during maturation. For many seeds, the ability to germinate develops first, followed by desiccation tolerance, vigor and potential storage life (Fig. 1). For seeds that are dry at maturity, these changes in quality correspond to changes in fresh weight and dry weight that occur during seed development. However, to ensure other characteristics affecting seed quality, such as resistance to drying, also called desiccation tolerance, stress tolerance during and after germination (vigor) and capacity for seed storage (storage life), seeds need to complete maturity on the maternal plants. The actual days to achieve each stage will vary by crop, but most seeds will follow a similar progression of quality improvement during development as illustrated in Fig. 1.

Following fertilization, cell division results in the formation of the embryonic tissues and the endosperm, followed by cell expansion largely by water uptake. Thus, seed fresh weight increases first, followed by an increase in dry weight as the storage materials, e.g., starch, oil, and proteins are deposited and replace cellular water. Seed water content declines during the seed maturation period, then falls more rapidly when the seeds desiccate prior to shedding. The actual days to development will vary by crop, but most orthodox seeds will follow a similar developmental progression as illustrated in Fig. 2.

Seed moisture content can therefore be a fairly reliable guide to seed maturity for determining harvest dates. For seeds that mature inside of fleshy fruits, such as tomatoes, peppers, melons or squashes, seed moisture content does not change significantly at maturity, and fruit maturity as indicated by ripening stage is a more reliable indicator of seed maturity. In general, optimal seed quality in these species coincides with fruit edible maturity, with both immature and overripe fruits yielding poorer quality seeds. Once the desiccation stage is completed, natural dispersal occurs in the case of wild species, but to a much lesser extent in cultivated varieties. Changes in fruit and seed coat color are useful markers of seed maturity.

The timing and methods of harvesting can markedly affect seed physiological quality, particularly in species with indeterminate flowering. In Brassicas, lettuce, carrots, and onions, for example, flowering continues sequentially within inflorescences, resulting in a wide range of seed maturity at a given time. In addition, these species are also subject to shattering, or loss of mature seeds due to fruit abscission. Thus, determining harvest dates in these crops is a compromise between allowing additional time for seed maturity and the danger of losing the most mature seeds, which are the earliest to set and often of the highest quality. In seeds such as beans, extreme care must be taken with the seed moisture content in order to avoid mechanical damage to seeds during seed extraction which would reduce seed quality.

Moisture content is commonly used to assess seed maturity. However, empirical determination of seed moisture content is destructive and requires laboratory facilities. There are now portable instruments available to determine the equilibrium relative humidity (eRH) - the RH of the air around a sample when the system is in equilibrium - of a seed sample. This can be used to decide whether it is appropriate to collect seed or how to process seed after collecting. In dry climates, if the eRH of seeds is already close to ambient RH, seeds should be collected as soon as possible. If fruits/seeds do not easily detach from the maternal plant and the eRH of seeds is still high (85-100%), it is better to wait for the fruit/seeds to further mature before a collection is made. When comparing seeds of different species it has been observed that seeds characterized by a slow rate of water loss during the desiccation phase have a higher desiccation sensitivity.

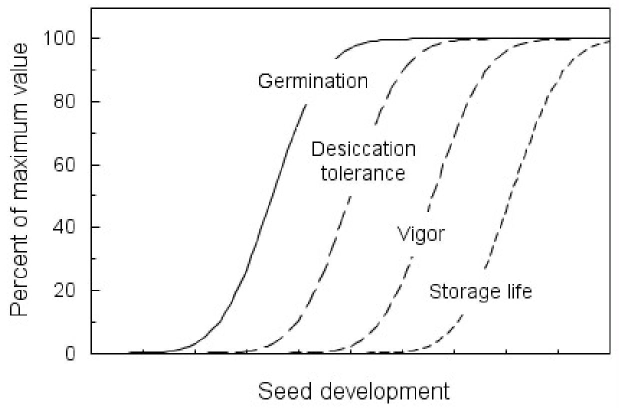

Figure 1. Sequential development of seed quality attributes during seed maturation.

Source: Bradford et al. 2012

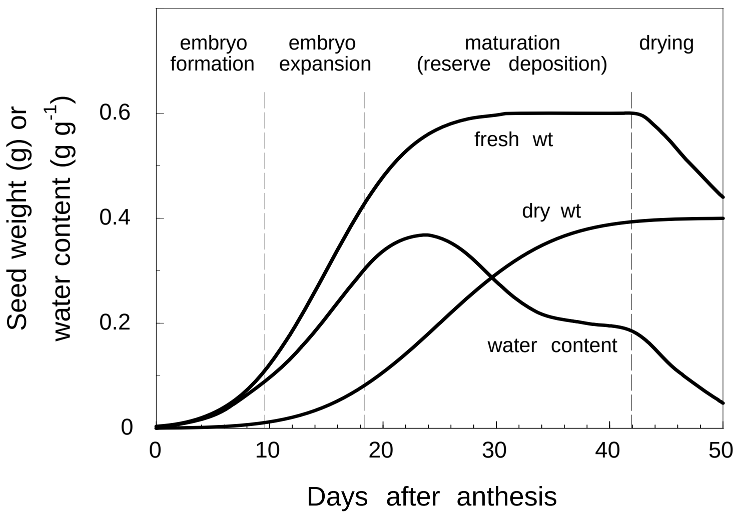

Figure 2. General scheme of development and maturation for orthodox seeds, i.e., seeds that naturally dehydrate at maturity.

Source: Bradford et al. 2012

3.5 Handling seeds at the time of collecting in the field/garden

How seeds are handled immediately after harvest is critical to their subsequent longevity in storage. If fruits/seeds are harvested at a very high eRH (85-100%) when they are still immature, they should not be rapidly dried, but kept under similar conditions in terms of temperature and humidity as on the mother plant to allow for further increase in seed quality. It would be best to simply keep intact fruits under shaded ambient conditions and/or partial sunlight to allow continued ripening of the seed (Table 1). If collected seed have an eRH of 50-85%, the expected rate of aging is high. Under hot and humid ambient conditions seeds need to be dried by placing them in a thin layer in a well ventilated, shaded location. Seeds should not be allowed to absorb moisture at night when ambient air humidity increases. This can be prevented by sealing them in air-tight containers. Seeds that are relatively dry at the time of collection (25-49% eRH) are loosely packed in mesh or paper bags in a well-ventilated, shaded location. Moisture absorption at night should be kept to a minimum.

The eRH of fleshy fruits (tomato, pepper, squashes) is always high, regardless of the maturity stage of the seeds inside. Seeds from such fruits should be extracted as soon as physical signs of maturity of the fruit (fruit color) become apparent.

Seed maturity stage	Seed moisture status	Ambient conditions	
		Dry (daytime RH < 50%)	**Humid (daytime RH > 50%)**
Immature	Wet (85% to 100% eRH)	Hold intact fruits under shaded ambient conditions for 1-2 weeks for continued ripening.	
At natural dispersal	Damp > 50% eRH	Dry in a thin layer, in a well-ventilated location. Minimize moisture absorption at night.	Transfer to drying room or dry with a desiccant such as silica gel (1:1 ratio) or place in air-conditioned room.
	Dry < 50% eRH	Hold in loosely packed mesh or paper bags in a well-ventilated, shaded location. Minimize moisture absorption at night.	

3.6 Seed drying

Seeds tend to absorb moisture from the surrounding air or give off moisture depending on the relative humidity and the gradient in water potential between the seed and surrounding air. If the water vapor pressure of the seed is greater than the surrounding air, the seed will lose moisture and become drier (desorption). If the water vapor pressure of a seed is lower than that of the surrounding air, the seed will gain moisture by absorption. Absorption or desorption occurs until the water vapor pressure in the seed and the surrounding air are balanced.

Equilibrium moisture content and moisture isotherms. The water content of seeds at equilibrium with the relative humidity of the surrounding air is referred to as equilibrium moisture content. Understanding the relationship between equilibrium seed moisture content and relative humidity is important in determining the appropriate drying regime for seeds. For a given species, there is a definable relationship between relative humidity and seed moisture content. Seeds will lose or absorb water until their moisture content is in balance with the RH of the surrounding air at that temperature. The relationship between seed moisture content and relative humidity is expressed by a sorption isotherm—this is simply a graph of seed moisture content against percentage relative humidity. Moisture isotherms depend on the chemical composition of seeds and differ between species, between accessions of the same species and even between seeds of the same accession harvested at different stages of development. Moisture isotherms are very useful in estimating the moisture content to which seeds can be dried in a given environment.

In most cases, seeds are harvested at moisture contents that are too high for safe storage. In general, starchy seeds should be stored at less than 12% moisture content (fresh weight basis), while oily seeds should be less than 9%. For sealed storage, seeds should be reduced to 4 to 7% seed moisture content. As every 1% increase in seed moisture content reduces potential seed storage life by half, control of seed moisture content is critical for the maintenance of seed quality.

Drying methods. There are several low-cost drying methods available to dry small quantities of seed.

<u>Shade-drying</u>

Shade-drying can be an effective way of reducing seed moisture content in environments where the RH is low (less than 40%); the lower the humidity, the more effective the drying process will be. Shade-drying is particularly useful for initial drying. Do not dry in the sun because it is believed to affect long-term seed viability in some species. Seeds are particularly sensitive to the combination of high moisture content and high temperature, so drying temperatures should not reach more than 30 ºC initially and can be raised as seed moisture content decreases. Drying temperatures should not exceed 43ºC in any case.

1. Sprinkle seeds in a single layer on a linen sheet or on open mesh racks placed in the shade, ensuring the free circulation of air. Any device that can increase the flow of air over the seeds (such as a fan) will improve drying efficiency.

2. Cover seeds with a protective net to prevent predation by animals (birds, rats, etc.).

3. At night, wrap the linen sheet and keep it in a cool room.

4. Allow enough time for seed moisture to reach equilibrium with the ambient RH—this may take several days.

In tropical countries with high RH, it is almost impossible to reach low seed moisture content with shade-dying. Under such conditions, self-defrosting refrigerators can be used, if available.

Self-defrosting refrigerator

Seeds can be dried using a self-defrosting refrigerator. The action of the self-defrost unit will maintain a low RH inside the refrigerator. It is difficult to control the exact RH, but this method is satisfactory if better means are not available. The RH in many refrigerators ranges from 10–40%, corresponding to seed moisture contents suitable for long- or medium-term conservation.

1. Spread seeds in a thin layer in an open container.

2. Place the container in a self-defrosting refrigerator and allow seeds to reach equilibrium with the humidity inside the refrigerator.

3. Seal the drying container tightly, remove it from the refrigerator and allow it to reach room temperature before opening it to prevent moisture from condensing on the seeds.

4. Seal the seeds in airtight containers and transfer them to storage.

Silica gel, a highly adsorbent gelatinous form of silica is commonly used as a dehumidifying and dehydrating agent and is a low-cost option for seed drying of small seed quantities (Fig. 3).

1. Place dried self-indicating blue silica gel in an airtight container (desiccators) or glass jar with an airtight seal. The weight of the silica gel used should be equal to that of the seeds for efficient drying (1:1 ratio). For faster drying, some genebanks use higher gel-to-seed ratios such as 3:1.

2. Place the seeds in porous bags and keep them in close proximity to the silica gel.

3. Keep the desiccator at a cool temperature (approximately 20°C).

4. Change the silica gel daily or when the color changes from deep blue to pink or pale blue.

5. Regenerate the silica gel by heating it in an oven at 100°C until it turns deep blue again. Allow it to cool in an airtight container before reusing.

6. Leave the seeds with fresh silica gel in the container until the moisture content of the seeds is in the range required for storage.

7. Pack the seeds in appropriate containers once the recommended moisture content or equilibrium seed weight is attained, and when the germination level and seed health are acceptable.

Once no further color change of the silica gel is observed (blue color is maintained) the seed is sufficiently dry and can be packaged for subsequent storage. Another very cheap and simple

salt test can be used by schools to show if seeds are dry enough to store. Mix common salt with seeds in a glass jar and shake for a couple of minutes. Leave for 10-20 minutes and examine the walls of the jar. If the seeds are still wet the salt will have absorbed moisture and will be sticking to the sides of the jar.

Figure 3. Left: blue-colored, regenerated silica gel at full capacity to absorb seed moisture; right: silica gel which has turned pink due to water adsorption from seeds and requires regeneration (heating in an oven).

3.7 Seed packaging and storage

The best time to package seeds is immediately after seed drying has been completed. Dry seeds will reabsorb moisture from more humid ambient air. Therefore, seeds should be packaged in waterproof containers and hermetically sealed without delay after the desired seed moisture content has been reached. This is meant to:

• prevent absorption of water from the atmosphere after drying;

• keep accessions separate and avoid mixing them; and

• prevent contamination from insects and diseases.

Types of container. Different types of container are available for packaging; the choice depends on storage conditions and species. It is important that the packing material be completely impermeable to water and suitable for long-term use. Frequently used containers include glass bottles, aluminium cans, laminated aluminium foil packets and plastic bottles.

Different types of container each have advantages and disadvantages. Glass bottles are good but can easily break. Aluminium cans are difficult to reseal once they have been opened.

Aluminum foil packets can be resealed and occupy less space than other containers, but seeds with sharp projections can pierce them and moisture can leak inside.

Plastic bottles and aluminium cans with lids are moisture resistant but not moisture proof unless they have a tight rubber seal. They should be used with caution if the RH of the storage room is not controlled.

Temperature. Once dry and properly packed, seeds should be stored at the lowest practicable temperature. A simple rule of thumb for medium-term storage is that the numerical sum of air relative humidity (%) plus storage temperature (ºC) should total less than 60 (or 100 if in ºF). For example, if seeds are in equilibrium with 50% relative humidity, the storage temperature should be less than 10ºC (50ºF). For most vegetable seeds, a temperature below 15 ^{o}C is ideal. Seeds in air-tight containers can be placed in a refrigerator, for example.

Darkness. Exposure to light will shorten the life of seeds. Therefore, dark-colored jars or non-transparent containers should be used to protect seed from light. If clear jars are used, these should be placed in paper bags to shield out light.

Most vegetable seeds can be safely stored for at least three to five years. It is important to label each container carefully with the name of the variety, the year of collection and any other information deemed important.

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4 School gardens and nutrition

Ray-Yu Yang and Jen Wen Luoh

AVRDC-The World Vegetable Center

Friday 30 August, Monday 2 September

4.1 Human nutrition

Human nutrition is the study of foods and how our bodies use them. It is concerned with how food is produced, processed, handled, sold, prepared, shared, and eaten, and the biochemical processes of foods in the body – how it is digested, absorbed, and used.

The science of nutrition moreover covers what foods are made of, how lifestyle choices affect nutritional needs, and other medical factors that define what we eat and why we eat it. Eating too little or too much food, and the types of foods can lead to long-term health consequences.

Dieticians, nutritionists, and nutrition workers are trained to educate and provide guidance about what to eat to ensure optimal health and performance.

4.2 Food Basics

Food is made up of many components including macronutrients, micronutrients, along with various chemical compounds and water.

Macronutrients are the main contributors of energy that our body uses and are needed in larger amounts compared to micronutrients. Macronutrients are classified as Carbohydrates, Protein, and Fats or Lipids.

Energy is used by the body to keep our bodies warm, build important tissues, secrete fluids such as saliva and breast milk, repair damaged tissues, and to move and work. It is measured in kilocalories (kcal) or kilojoules (kj). 1 kcal is equal to 4184 kj.

Carbohydrates are molecules made up of one or more sugar molecules consisting of carbon, hydrogen and oxygen (C, H, O) and thus abbreviated as CHO. Carbohydrates contribute the majority of energy for our body. Simple CHO provide instant source of energy because they are rapidly digested and absorbed into blood stream. Complex CHO take longer to digest, so their energy is released slowly and provide energy to fuel activity over a longer period of time. Fiber is not an energy, but important for helping to move solid wastes through the digestive tract.

Categories of carbohydrates	Types of carbohydrates	Food sources
Simple carbohydrates (single and short-chain of sugar molecules)	Glucose (blood sugar) Fructose (fruit sugar) Sucrose (table sugar) Lactose (milk sugar) Oligosaccharides	sugars, honey, fruits, soda, sweets,
Complex carbohydrates (long chains of glucose molecules)	Starch (storage form of glucose in plants), Glycogen (storage form of glucose in animals and humans) Fiber (Indigestible, nonabsorbable plant remnant)	Tubers (potato, squash), grain (oats, corn), legumes (soybean), cereals, fruits

Protein is involved in growth, maintenance, and repair of all tissues in the body. Complex protein molecules are made of chains of amino acids (AA). About 80 different AA in nature, but the human body needs only 20 to function. In digestion, the protein is broken down to AAs for the body to use. AAs could be essential or non-essential. Essential AA cannot be made by the body and must be obtained through food while non-essential AA can be made by the body.

<u>Essential amino acid:</u>

Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan, Valine

<u>Non-essential amino acid:</u>

Alanine, Asparagine, Aspartic acid, Glutamic acid, Arginine, Glycine, Cysteine, Ornithine, Glutamine, Proline, Tyrosine, Serine

Foods containing all essential AAs are called, “Complete” protein source. These include: meat, fish, dairy products, and soy. Foods that are missing one or more of the essential AAs are called, “Incomplete” protein sources and could be combined with other foods to provide all the essential AAs. Incomplete protein sources include nuts, seeds, and legumes.

Lipids are fats and oils that provide energy and serves as a cushioning layer to protect individual parts of the body from physical or mechanical damage. Lipids also contribute to the flavor and mouthfeel of foods.

Lipids are classified as:

Categories of lipids	Function
Triglycerides	95% of dietary fat comes from triglycerides The major form of lipid in food & in the body
Phospholipids	Allow water & fats to mix Has hydrophilic phosphate head & hydrophobic fat-soluble tail
Sterols	Form cholesterol, vitamin D, sex hormones, cortisol (stress hormone)

Fats also have different degrees of saturation, in which the differences in the amount of double bonds of its chemical structure determine the fat's solidity at room temperature.

Types of fats	State at room temperature	Food sources
Saturated fats • Triglycerides containing fatty acids with no double bonds	Solid	Coconut oil, butter, and lard
Monounsaturated fats (MUFA) • Triglyceride containing fatty acids with a single double bond	Liquid	Olive and peanut oils
Polyunsaturated fats (PUFA) • Triglycerides containing fatty acids with multiple double bonds	Liquid	Corn, soy, canola and sunflower oils

Fatty acids are a type of lipid made of from a chain of 2 to 24 carbon atoms linked together. Similar to amino acid, some fatty acids are considered essential because they can be supplied only through diet. Linoleic and linolenic acids are essential fatty acids needed by the body to maintain cell membranes, produce substances that regulate blood pressure, help with blood clot formation, regulate blood lipid levels, and help with immune responses to infection.

Eating fats can be good or bad depending on the amounts and kinds of fat or oil consumed. A low fat diet with less saturated fat than unsaturated fat, and containing essential fatty acids is recommended.

Micronutrients are vitamins and minerals that are required in smaller amounts by the body. Although they are needed in small amounts, a deficiency in vitamins and minerals can cause serious health problems.

Vitamins are divided into fat-soluble and water-soluble vitamins. Fat soluble vitamins include vitamins A, D, E, K and water-soluble vitamins are vitamins B and C.

Vitamins	Functions	Food Sources
Vitamin A (and its precursor*, beta-carotene) *A precursor is converted by the body to the vitamin.	Needed for vision, healthy skin and mucous membranes, bone and tooth growth, immune system health	Vitamin A from animal sources (retinol): fortified milk, cheese, cream, butter, fortified margarine, eggs, liver Beta-carotene (from plant sources): Leafy, dark green vegetables; dark orange fruits (apricots, cantaloupe) and vegetables (carrots, winter squash, sweet potatoes, pumpkin)
Thiamine (vitamin B1)	Part of an enzyme needed for energy metabolism; important to nerve function	Found in all nutritious foods in moderate amounts: pork, whole-grain or enriched breads and cereals, legumes, nuts and seeds
Riboflavin(vitamin B2)	Part of an enzyme needed for energy metabolism; important for normal vision and skin health	Milk and milk products; leafy green vegetables; whole-grain, enriched breads and cereals
Niacin (vitamin B3)	Part of an enzyme needed for energy metabolism; important for nervous system, digestive system, and skin health	Meat, poultry, fish, whole-grain or enriched breads and cereals, vegetables (especially mushrooms, asparagus, and leafy green vegetables), peanut butter
Pantothenic acid	Part of an enzyme needed for energy metabolism	Widespread in foods
Biotin	Part of an enzyme needed for energy metabolism	Widespread in foods; also produced in intestinal tract by bacteria
Pyridoxine (vitamin B6)	Part of an enzyme needed for protein metabolism; helps make red blood cells	Meat, fish, poultry, vegetables, fruits
Folic acid	Part of an enzyme needed for making DNA and new cells, especially red blood cells	Leafy green vegetables and legumes, seeds, orange juice, and liver; now added to most refined grains
Cobalamin (vitamin B12)	Part of an enzyme needed for making new cells; important to nerve function	Meat, poultry, fish, seafood, eggs, milk and milk products; not found in plant foods
Ascorbic acid (vitamin C)	Antioxidant; part of an enzyme needed for protein metabolism; important for immune system health; aids in iron absorption	Found only in fruits and vegetables, especially citrus fruits, vegetables in the cabbage family, cantaloupe, strawberries, peppers, tomatoes, potatoes, lettuce, papayas, mangoes, kiwifruit
Vitamin D	Needed for proper absorption of calcium; stored in bones	Egg yolks, liver, fatty fish, fortified milk, fortified margarine. When exposed to sunlight, the skin can make vitamin D.
Vitamin E	Antioxidant; protects cell walls	Polyunsaturated plant oils (soybean, corn, cottonseed, safflower); leafy green vegetables; wheat germ; whole-grain products; liver; egg yolks; nuts and seeds
Vitamin K	Needed for proper blood clotting	Leafy green vegetables and vegetables in the cabbage family; milk; also produced in intestinal tract by bacteria

Data source: Vitamins & Supplements (2011) WebMD Medical Reference from Healthwise: http://www.webmd.com/vitamins-and-supplements/vitamins-and-their-functions-and-sources

Minerals that the body needs are called essential minerals and could be divided into major minerals and minor (trace) minerals. Both group are equally important, but required in different amounts in the body.

Minerals	Functions	Food Sources
Major minerals		
Sodium	Needed for proper fluid balance, nerve transmission, and muscle contraction	Table salt, soy sauce; large amounts in processed foods; small amounts in milk, breads, vegetables, and unprocessed meats
Chloride	Needed for proper fluid balance, stomach acid	Table salt, soy sauce; large amounts in processed foods; small amounts in milk, meats, breads, and vegetables
Potassium	Needed for proper fluid balance, nerve transmission, and muscle contraction	Meats, milk, fresh fruits and vegetables, whole grains, legumes
Calcium	Important for healthy bones and teeth; helps muscles relax and contract; important in nerve functioning, blood clotting, blood pressure regulation, immune system health	Milk and milk products; canned fish with bones (salmon, sardines); fortified tofu and fortified soy milk; greens (broccoli, mustard greens); legumes
Phosphorus	Important for healthy bones and teeth; found in every cell; part of the system that maintains acid-base balance	Meat, fish, poultry, eggs, milk, processed foods (including soda pop)
Magnesium	Found in bones; needed for making protein, muscle contraction, nerve transmission, immune system health	Nuts and seeds; legumes; leafy, green vegetables; seafood; chocolate; artichokes; "hard" drinking water
Sulfur	Found in protein molecules	Occurs in foods as part of protein: meats, poultry, fish, eggs, milk, legumes, nuts
Minor minerals		
Iron	Part of a molecule (hemoglobin) found in red blood cells that carries oxygen in the body; needed for energy metabolism	Organ meats; red meats; fish; poultry; shellfish (especially clams); egg yolks; legumes; dried fruits; dark, leafy greens; iron-enriched breads and cereals; and fortified cereals
Zinc	Part of many enzymes; needed for making protein and genetic material; has a function in taste perception, wound healing, normal fetal development, production of sperm, normal growth and sexual maturation, immune system health	Meats, fish, poultry, leavened whole grains, vegetables
Iodine	Found in thyroid hormone, which helps regulate growth, development, and metabolism	Seafood, foods grown in iodine-rich soil, iodized salt, bread, dairy products
Selenium	Antioxidant	Meats, seafood, grains
Copper	Part of many enzymes; needed for iron metabolism	Legumes, nuts and seeds, whole grains, organ meats, drinking water
Manganese	Part of many enzymes	Widespread in foods, especially plant foods

Fluoride	Involved in formation of bones and teeth; helps prevent tooth decay	Drinking water (either fluoridated or naturally containing fluoride), fish, and most teas
Chromium	Works closely with insulin to regulate blood sugar (glucose) levels	Unrefined foods, especially liver, brewer's yeast, whole grains, nuts, cheeses
Molybdenum	Part of some enzymes	Legumes; breads and grains; leafy greens; leafy, green vegetables; milk; liver

Data source: Minerals & Supplements (2011) WebMD Medical Reference from Healthwise: http://www.webmd.com/vitamins-and-supplements/minerals-and-their-functions-and-sources

Plant-based foods also contain **bioactive phytochemicals** that are beneficial to health. These are non-nutrient compounds in plants with health related functions associated with lower risks of chronic diseases such as cancer, heart diseases, and type II diabetes.

Anti-nutrient factors can be found in foods that inhibit the absorption of other nutrients. For example:

Anti-nutrient	Limits absorption of
Phytic acids in legumes	Iron
Polyphenolics in plants	Minerals
Tannic acid in plants	Minerals
Oxalic acid in vegetables such as spinach	Minerals
Trypsin inhibitor in soybean	Protein

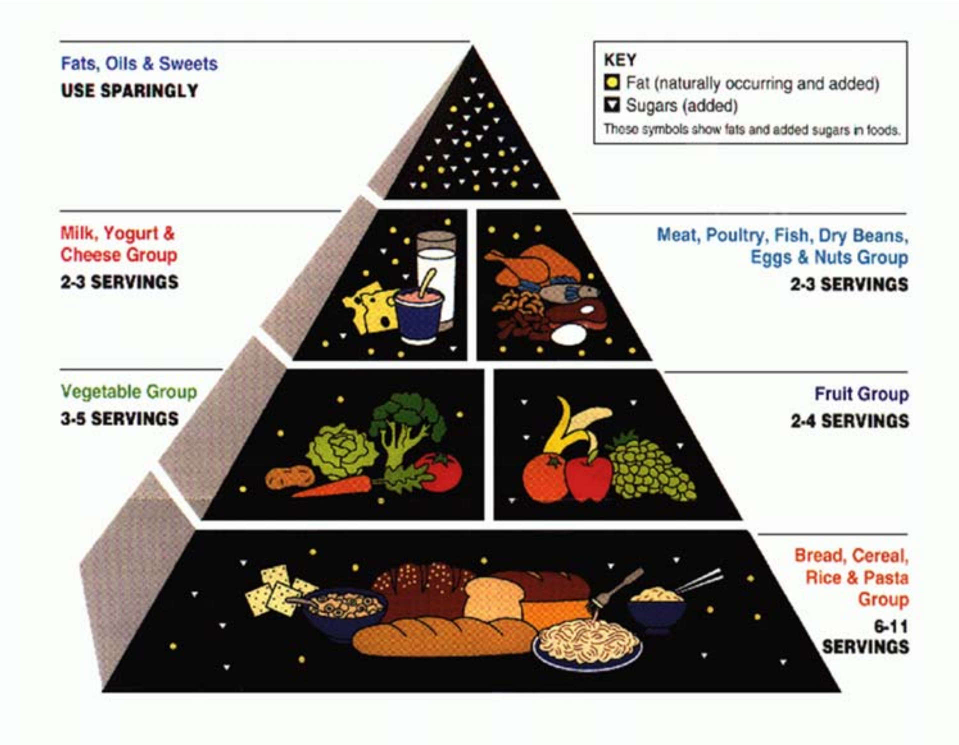
The recommended intakes of each nutrient are specified using **Dietary Reference Intakes (DRI)** developed through intensive review of scientific researches by the Institute of Medicine. The DRIs could be found online at: http://fnic.nal.usda.gov/dietary-guidance/dietary-reference-intakes/dri-tables.

Recommended nutrient intake (RNI) is used by FAO and WHO as a standard daily nutrient requirement. The RNI meets the nutrient requirements of almost all (97.5%) apparently healthy individuals in an age- and sex-specific population. RNIs could be found online at: http://www.who.int/nutrition/publications/nutrientrequirements/en/index.html

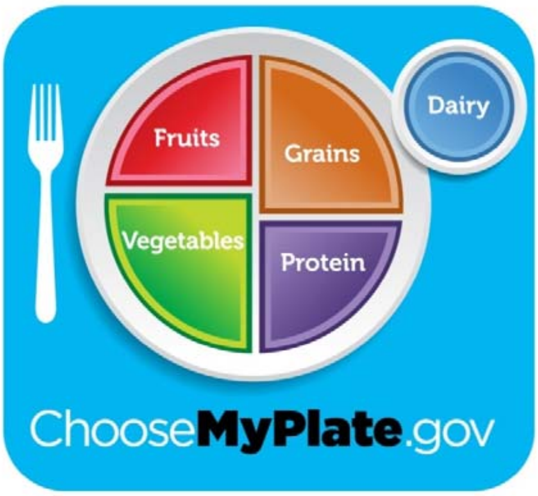
4.3 Balanced and healthy Diet

A healthy diet includes eating a variety of foods from the different food groups. Many countries have developed their own dietary guidelines to help people meet their dietary requirements through eating the right foods. The guidelines are science-based advice for ages 2 and over to promote health and prevent chronic disease.

For example, the United States previously used a Food Guide Pyramid to guide people on their daily food consumptions.



Recently, the country has opted for a plate-shaped food guide called, "MyPlate". For information on MyPlate, you can visit their website: http://www.choosemyplate.gov/



Vegetables	Fruits	Grains	Dairy	Protein Foods
Eat more red, orange, and dark-green veggies like tomatoes, sweet potatoes, and broccoli in main dishes. Add beans or peas to salads (kidney or chickpeas), soups (split peas or lentils), and side dishes (pinto or baked beans), or serve as a main dish. Fresh, frozen, and canned vegetables all count. Choose "reduced sodium" or "no-salt-added" canned veggies.	Use fruits as snacks, salads, and desserts. At breakfast, top your cereal with bananas or strawberries; add blueberries to pancakes. Buy fruits that are dried, frozen, and canned (in water or 100% juice), as well as fresh fruits. Select 100% fruit juice when choosing juices.	Substitute whole-grain choices for refined-grain breads, bagels, rolls, breakfast cereals, crackers, rice, and pasta. Check the ingredients list on product labels for the words "whole" or "whole grain" before the grain ingredient name. Choose products that name a whole grain first on the ingredients list.	Choose skim (fat-free) or 1% (low-fat) milk. They have the same amount of calcium and other essential nutrients as whole milk, but less fat and calories. Top fruit salads and baked potatoes with low-fat yogurt. If you are lactose intolerant, try lactose-free milk or fortified soymilk (soy beverage).	Eat a variety of foods from the protein food group each week, such as seafood, beans and peas, and nuts as well as lean meats, poultry, and eggs. Twice a week, make seafood the protein on your plate. Choose lean meats and ground beef that are at least 90% lean. Trim or drain fat from meat and remove skin from poultry to cut fat and calories.
For a 2,000-calorie daily food plan, you need the amounts below from each food group. To find amounts personalized for you, go to Choose**MyPlate**.gov.				
Eat 2½ cups every day **What counts as a cup?** 1 cup of raw or cooked vegetables or vegetable juice; 2 cups of leafy salad greens	**Eat 2 cups every day** **What counts as a cup?** 1 cup of raw or cooked fruit or 100% fruit juice; ½ cup dried fruit	**Eat 6 ounces every day** **What counts as an ounce?** 1 slice of bread; ½ cup of cooked rice, cereal, or pasta; 1 ounce of ready-to-eat cereal	**Get 3 cups every day** **What counts as a cup?** 1 cup of milk, yogurt, or fortified soymilk; 1½ ounces natural or 2 ounces processed cheese	**Eat 5½ ounces every day** **What counts as an ounce?** 1 ounce of lean meat, poultry, or fish; 1 egg; 1 Tbsp peanut butter; ½ ounce nuts or seeds; ¼ cup beans or peas

FAO has a database of food-based dietary guidelines listed by country:
http://www.fao.org/ag/humannutrition/nutritioneducation/fbdg/en/

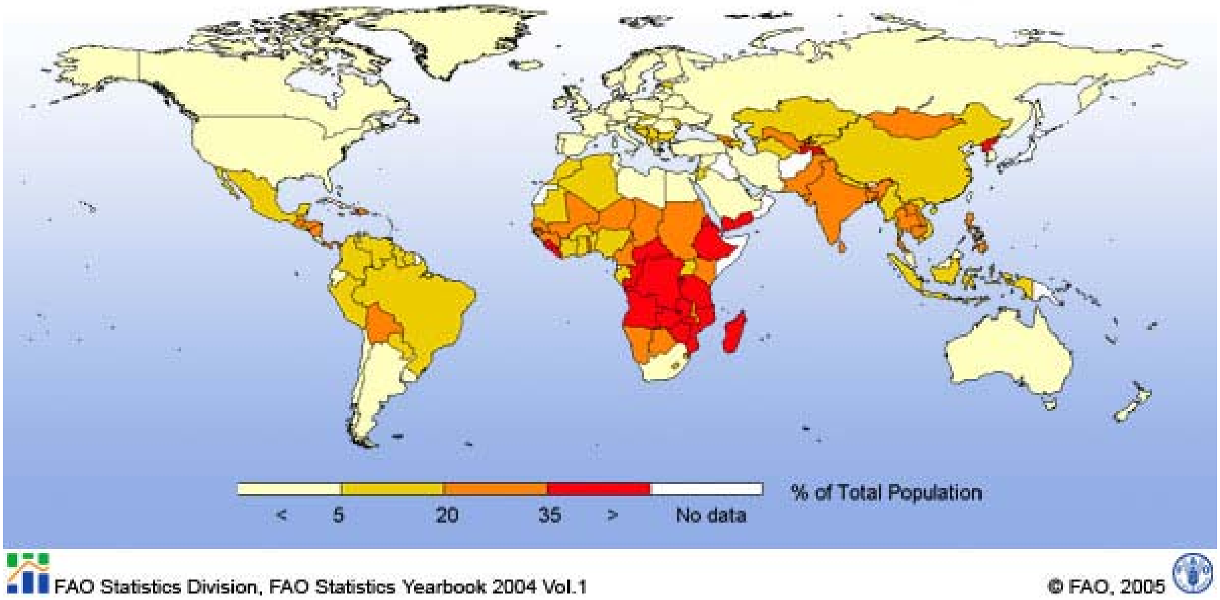
General recommendations from the Dietary Guidelines for Americans (2005) suggests:

Focus areas	Recommendations
Adequate Nutrients Within Calorie Needs	• Consume a variety of nutrient-dense foods and beverages within and among the basic food groups while choosing foods that limit intake of saturated and *trans* fat, cholesterol, added sugars, salt, and alcohol
Physical Activity	• Engage in regular physical activity and reduce sedentary activities to promote health, psychological well-being, and a health body weight • Children and adolescents – At least 60 minutes, preferably all, days of the week.
Weight Management	• To maintain body weight in a healthy range, balance calories from foods and beverages with calories expended. • To prevent gradual weight gain over time, make small decreases in food and beverage calories and increase physical activity
Food Groups To Encourage	• Consume sufficient amts. of fruits & vegetables while staying within energy needs • For 2000 calories: 2 cups of fruit, 2½ cups of vegetables • Choose a variety of fruits and vegetables • Consume 3 oz. equivalents of whole grains daily—at least half whole grains (rest enriched) • Consume 3 cups per day of fat-free or low-fat milk or equivalent milk products
Fats	• Consume less than 10 % of calories from saturated fatty acids, less than 300 mg/day of cholesterol and keep trans fatty acids as low as possible • Total fat between 20 to 35 % with most fats from sources of PUFAs and MUFAs, such as fish, nuts, and vegetable oils • Select and prepare meat, poultry, dry beans, and milk or milk products that are lean, low-fat, or fat-free • Limit intake of fats and oils high in saturated and/or trans fatty acids
Carbohydrates	• Choose fiber-rich fruits, vegetables, and whole grains • Choose and prepare foods and beverages with little added sugars or caloric sweeteners • Consume sugar- and starch-containing foods and beverages less frequently to reduce caries
Sodium and Potassium	• Consume < 2,300 mg (~1 tsp. salt) of sodium per day • Choose and prepare foods with little salt. At the same time, consume potassium-rich foods, such as fruits and vegetables.
Alcoholic Beverages	• Those who choose to drink alcoholic beverages should do so sensibly and in moderation – defined as the consumption of up to one drink per day for women and up to two drinks per day for men. • Alcoholic beverages should not be consumed by some individuals • Alcoholic beverages should be avoided by individuals engaging in activities that require attention, skill, or coordination
Food Safety	To avoid microbial foodborne illness: • Clean hands, food contact surfaces, and fruits and vegetables. Meat and poultry should not be washed or rinsed.

	• Separate foods • Cook foods to safe temperature • Chill perishable foods promptly. • Avoid unpasteurized milk, raw eggs, raw or undercooked meat and poultry, unpasteurized juices, and raw sprouts.

4.4 Nutrition and global health

Malnutrition can be divided into three forms: 1) undernutrition, 2) micronutrient deficienciesand 3) overweight and obesity.



Clinically, undernutrition is characterized by inadequate intake of protein, energy, and micronutrients and by frequent infections or diseases. Nutritional deficiencies affect over 144 million people worldwide, severely affecting women and young children.

Types and effects of malnutrition, and number affected globally

Type of Malnutrition	Nutritional Effect	Number Affected Globally (billion)
Hunger	Deficiency of calories and protein	At least 1.1
Micronutrient Deficiency	Deficiency of vitamins and minerals	2.0 - 3.5
Over consumption	Excess of calories often accompanied by deficiency of vitamins and minerals	At least 1.1

Note: Hunger and over consumption correspond to underweight or overweight populations. There is considerable overlap between micronutrient deficiency and other forms of malnutrition.

Source: World Watch Paper 150, 2000

Protein-energy malnutrition (PEM): The most lethal form of malnutrition where children are its most visible victims. At least half of the 10.4 million child deaths are attributed to PEM each year. Protein-energy malnutrition is usually measured in terms of body size.

<u>Indicators in children</u>

Stunting: low height-for-age

Underweight: low weight-for-age

Wasting or acute malnutrition: low weight-for-height

<u>Indicators in adults</u>

Low body mass index (BMI)

Most severe **micronutrient deficiencies** include vitamin A, iodine, iron and zinc deficiencies. Strategies to decrease nutritional deficiencies include fortification of foods, supplementation, and increasing availability of sources.

Vitamin A Deficiency (VAD) affects between 100 and 140 million children in the world. An estimated 250 000 to 500 000 vitamin A-deficient children become blind every year, half of them are dying within 12 months of losing their sight. Nearly 600 000 women die from childbirth-related causes each year.

Iodine Deficiency Disorder (IDD) affects over 740 million people, 13% of the world's population; 30% of the remainder are at risk. IDD preys upon poor, pregnant women and preschool children, posing serious public health problems in 130 developing countries. Nearly 50 million people suffer from some degree of IDD-related brain damage. Small quantities of iodine at low cost can solve the problem. Most countries have iodized their salt and have significantly reduced the number of people with IDD.

Iron deficiency anemia (IDA) is the main cause of anemia. Nine out of ten anemia sufferers live in developing countries; on average, every second pregnant woman and four out of ten preschool children are anemic. In many developing countries, iron deficiency anemia is aggravated by worm infections, which cause blood loss to some 2 billion people worldwide; and malaria, which affects 300-500 million people. In some areas, malaria may be the primary cause of half of all severe anemia cases.

Intervention package features:

<u>Increased iron intake</u>

- Iron supplements, iron-rich diets, increasing iron absorption and fortification.

Infection control

- Public health measures to control hookworm infections, malaria and schistosomiasis.

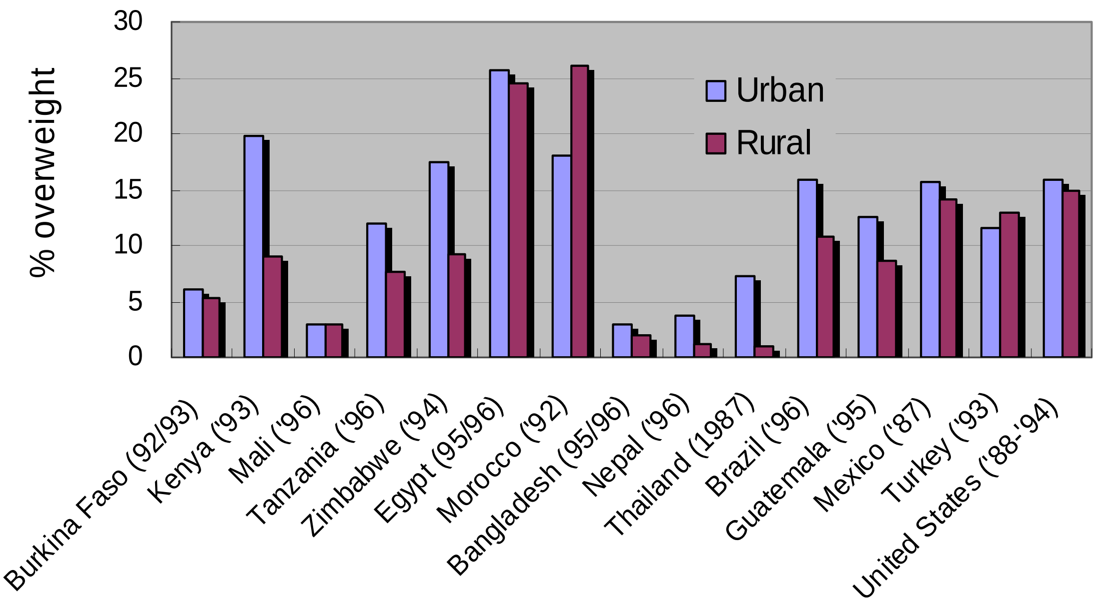
Improved nutritional status

- Control of major nutrient deficiencies, diet diversification and infection prevention.

Zinc Deficiency is usually the result of a poor diet where the person would lack other nutrients and calories at the same time. Zinc deficiency is the cause of slow growth, slow sexual development in boys, slow wound healing, poor appetite, apathy, skin changes, and diarrhea.

Double burden of malnutrition is a common phenomenon around the world where undernutrition and overnutrition co-exists in the same country. This is largely due to countries undergoing nutrition transition. The transition is a shift from traditional lifestyles to "Western" diets such as high in saturated fats, sugar and refines foods. The combination of reduced levels of physical activities and increased stress, particularly in the rapid growing urban population had led to increased levels of obesity, and chronic and degenerative diseases.

Overweight in preschool children in developing countries by residence



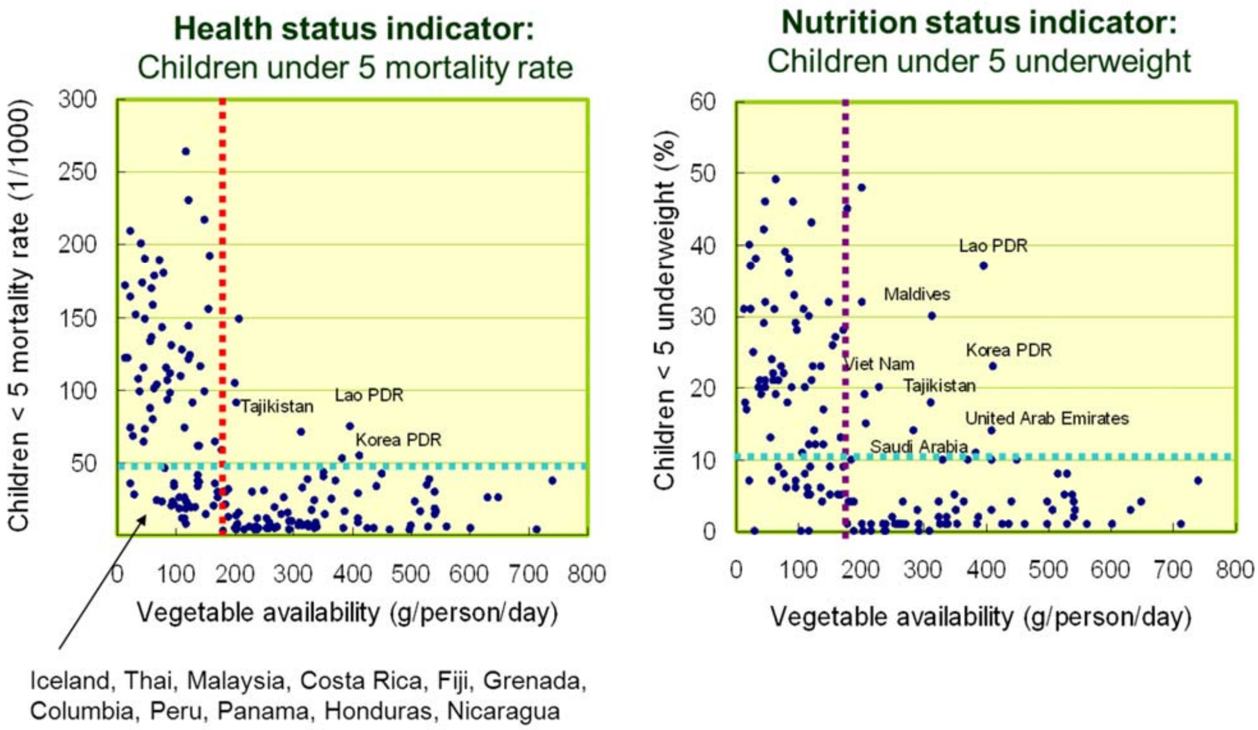
Source: Martorell, 2000

4.5 Nutrition and vegetables

Vegetables are key sources of micronutrients and beneficial phytocompounds, meeting a substantial part of daily micronutrient needs. They contribute to diversity of ecosystem, agricultural system and human diets. At AVRDC-The World Vegetable Center, we have collected and conserved more than 59,507 accessions of vegetable seeds from 156 countries, including about 12,000 accessions of indigenous vegetables.

Consuming vegetables is related to better nutrition and health outcomes.

National vegetable availability vs. health/nutrition status



Data source for the correlation test: FAOSTAT and WHO

Nutritive content in vegetables, cereals and livestock products per 100 g edible portion

Product	Energy Calories	Protein g	Calcium mg	Iron mg	Vit A µg RE	Vit C mg
Common Vegetables						
Tomato	19	1.1	6	0.6	79	22
Sweet pepper	23	1.1	10	0.8	253	90
Onion	31	2.7	53	2.3	153	32
Squash	37	1.0	20	0.4	181	10
Common cabbage	19	1.4	47	0.7	40	39
Cereals						
Rice	158	2.8	4	0.9	0	0
Starchy roots and stems						
Taro	78	1.8	28	1.0	tr.	7
Legumes, seeds and nuts						
Red bean	301	22.2	242	6.1	6	0
Livestock products						
Chicken	87	16.4	9	0.9	3	0
Milk	65	3.4	142	0.1	25	1
Beef	218	13.8	6	1.8	24	0

Distribution of nutrient values among vegetables

In 100 g fw	*N*	*Min*	*Max*	*Mean*	*SD*
Protein, g	243	0.2	10	3	1.6
β-carotene, mg	241	0.0	22	3.1	3.3
Vit. C, mg	243	1.1	353	70	77
Vit. E, mg	243	0.0	71	2.6	5.6
Folates, µg	90	2.8	175	51	40
Ca, mg	243	2	744	121	136
Fe, mg	243	0.2	26	2.1	2.6
Zn, mg	27	0.17	1.24	0.49	0.24
Total phenol, mg	241	17	12,070	444	940
AOA, TE	243	0.63	82,170	1383	5648

Indigenous vegetables are suitable and often highly nutritious vegetables that could contribute significantly to a healthy diet. Due to its relatively easy cultivation, these vegetables can be promoted in the local school and home gardens. The following are characteristics of indigenous vegetables:

- Native to the regions
- Long been used in diets
- Important role in biodiversity and diverse diet
- Grown locally on a small scale
- Often tolerant to environmental stress
- Most are underutilized
- Limited Information on nutrient values, bioactive compounds, anti-nutrients, and potential health hazards

Vegetable Groups by PROTA (Plant Resources of Tropical Africa)

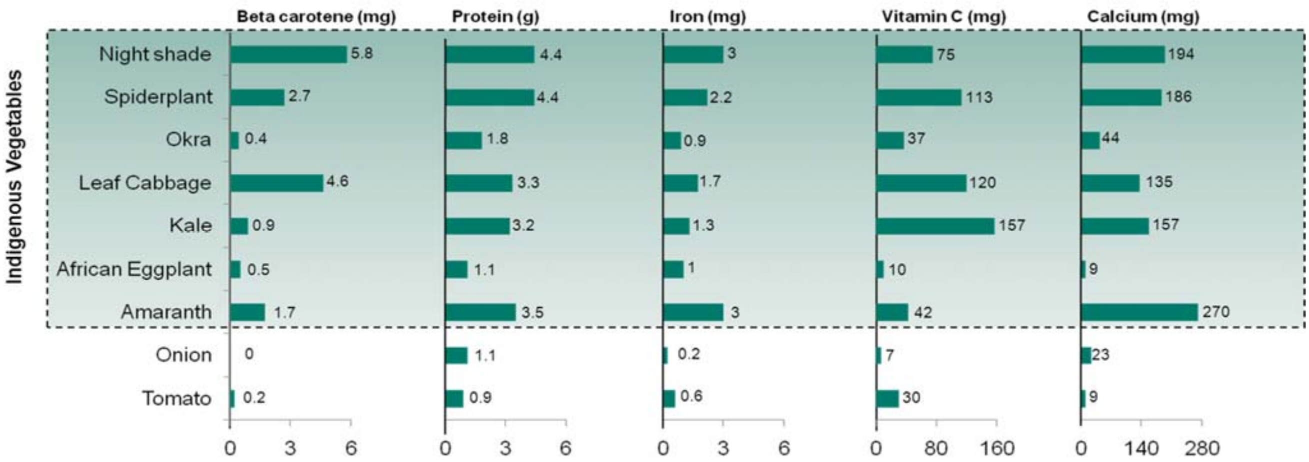
Exotic: Vegetables are recently introduced	Amaranth, celery, chaya, Chinese cabbage, garden beet, kohlrabi, leek, great-headed garlic, pearl onion, New Zealand spinach, pakchoi, prince's feather, turnip, wax gourd, Welsh onion, winged bean…
Adapted vegetables were introduced long ago and widely adapted	Amaranth, brown mustard, capsicum, carrot, chayote, cucumber, drumstick tree, eggplant, flameflower, French bean, garden rocket, garlic, headed cabbage, leaf cabbage, lettuce, musk pumpkin, onion, shallot, pumpkin, radish, snake gourd, sword bean, taro, tomato….
Indigenous vegetables are native to the regions	African eggplant, African nightshade, wild amaranth, baobab, bitter gourd, bitter lettuce, bitterleaf, black nightshade, wild bottle gourd, bottle lettuce, burweed, celosia, common okra, cowpea, yard-long bean, wild cucumber, Ethiopian kale, fluted pumpkin, gboma, giant yellow mulberry, gooseberry cucumber, ivy gourd, Jew‘s mallow, lablab, purslane, roselle, sorrel, spiderplant…..

Content range of nutrient and anti-nutrient components of three groups of vegetables used in Africa

Vegetable groups		DM %	A mg	C mg	E mg	F µg	Ca mg	Fe mg	Zn mg	AOA ugTE	TP g	Oxa mg
Exotic total n=13	min	3.9	0.01	3	0.27	5	18	0.20	0.00	388	80	196
	max	23.2	14.00	242	1.40	159	358	6.50	1.28	685	128	915
	median	7.8	0.96	27	0.75	31	67	0.99	0.17	560	112	244
	mean	10.4	2.52	50	0.73	47	123	1.63	0.37	544	107	452
	stdev	6.5	4.70	67	0.46	45	122	1.83	0.39	149	24	402
	n	13	8	13	5	11	12	13	11	3	3	3
Adapted total n=33	min	4.2	0.00	3	0.00	3	9	0.21	0.00	276	26	21
	max	41.4	8.29	221	4.52	140	589	8.90	1.48	3838	543	479
	median	9.4	0.39	30	0.62	37	67	0.98	0.29	768	120	68
	mean	11.0	1.88	46	1.03	47	135	1.63	0.46	1084	176	193
	stdev	7.2	2.42	49	1.19	35	160	1.87	0.38	972	150	196
	n	31	31	30	20	23	31	31	20	13	13	9
Indigenous total n=73	min	4.3	0.02	3	0.05	3	3	0.20	0.00	164	24	8
	max	25.5	12.59	400	17.72	198	711	29.20	3.10	13506	2140	353
	median	13.0	2.14	40	1.40	70	172	1.81	0.46	847	204	33
	mean	14.7	2.78	56	2.23	71	185	3.30	0.56	1683	345	67
	stdev	11.9	2.99	68	3.72	56	165	4.96	0.72	2727	464	95
	n	54	30	39	21	15	54	45	17	22	21	14

(1) DM: dry matter, A: β-carotene, C: vitamin C, E: α-tocopherols; AOA: antioxidant activity; TE: tolox equivalent; TP: total phenolics, Oxa: oxalate (2)Vegetable grouping according to PROTA. Exotic: vegetables are recently introduced; Adapted: vegetables were introduced long ago and widely adapted; Indigenous: Vegetables are native to Africa. (3) n: number of vegetables with available nutrient data

Nutrient content of indigenous vegetables compared to onion and tomato



Data source: "Advancing urban agriculture through use of indigenous vegetables: African experiences 2009; Chapter 3”, by Ray-Yu Yang and Gudrun B. Keding

Vitamin A, iron and zinc in Indigenous Vegetables

Many plants contain more than 50% RNI (Recommended Nutrient Intake) of Vitamin A content. Since indigenous vegetables are similar in tropical Asian countries and parts of Africa, Vitamin A content is relatively high in indigenous vegetables.

Indigenous vegetables have low iron content and low bioavailability. Some plants have higher iron stores (eg. Chinese honeysuckle which covers 58% RNI).

There are even less zinc content in plants than Iron. Amaranth, especially livid amaranth have a higher Zinc content (8-37% RNI coverage).

Important indigenous vegetables

Amaranth: Pantropic leafy vegetable with high levels of nutrients

- Livid Amaranth (Amaranthus lividus): covering 37% RNI Zinc
- Spleen Amaranth (Amaranthus dubius): covering 19% RNI Iron, and 62% RNI Calcium

Jute: At least one species found in every country. The different parts can be eaten for different nutrients

- Jute (Corchorus capsularis): covers 285% RNI Vitamin A
- Jute Mallow (Corchorus olitorius): covers 226% RNI Vitamin A

Cassava (*Manihot esculenta*): Pantropic root used as staple. The leaves have very high vitamin A and C. Traditional cooking removes toxins.

Vegetable Cowpea (*Vigna unguiculata)*: Pantropic vegetable used both as a pulse and leafy vegetable high vitamin A and calcium.

Drumstick tree (*Moringa oleifera*): Pantropic vegetable used as leafy vegetable and water purifier. Leaf powder is in use to fight malnutrition in West Africa.

4.6 Nutrition for school-aged children

School-aged children from ages 5 to adolescent are in a period of rapid growth and need to be well nourished to encourage healthy growth and development. Healthy children learn better, grow up to become healthy adults that are stronger, more productive and more able to create opportunities to gradually break the cycles of both poverty and hunger in a sustainable way. Girls also become healthy mothers who can nurse healthy babies with stronger immune systems and fewer illnesses.

Children and adolescents need three good mixed meals each day and snacks between meals that are nutrient dense. Younger children may have smaller appetites, thus nutrient-dense foods can provide more nutrients and energy than other foods. Eating habits are shaped at a young age through interaction with the family. Later, as they grow up, experiences at school and with friends will shape their food preferences and dietary habits. A basic understanding of the principles of healthy eating can let students make healthy food choices.

All children are encouraged to eat a variety of foods and follow dietary guidelines and DRI or RNI for their age group.

Additional dietary recommendations for students include:

Focus areas	Recommendations
Fish (if possible)	• If possible, eat 2 portions of fish per week for protein and beneficial omega-3 fatty acids
Snacks	• Snacks should be nutrient-dense and low in sugar, sodium, and fat • For example: one fruit, a glass of milk or soy milk, a handful of nuts
Sodium (salt)	• Children should be encouraged not to add any salt to their foods and are recommended to consume: o Children aged 4 to 6 years – no more than 3 g a day; o Children aged 7 to 10 years – no more than 5 g a day; o Children aged 11 or above – no more than 6 g a day.
Breakfast	• Breakfast is important for supplying children's energy for their morning activities. • Children who eat a healthy breakfast are less likely to snack on foods that are high in fat and/or sugar and tend to have a better nutrient intake throughout the day • Breakfast choices which are nutrient-dense and release energy slowly are the preferred options.
School meals	• School meals with nutrient-dense foods low in sugar, sodium, and fat are recommended • Meals should include a variety of foods from the different food groups
Physical activity	• Physical activity in childhood can help children maintain a healthy weight, and reduce the risk of type 2 diabetes or cardiovascular disease and help maintain bone health • Children and young people should engage in at least 60 minutes of moderate intensity physical activity each day. • At least twice a week, this should include activities that improve bone health, muscle strength and flexibility, for example running, cycling or swimming (respectively).

4.7 Food-based approaches

Food security was defined in 1996 by the World Food Summit as "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life." The concept includes the following 4 pillars:

- Food availability: sufficient quantities of food available on a consistent basis.
- Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.
- Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

- Stable food supply

Food security is an issue linked to health and malnutrition, economic development and poverty, agriculture, environment and trade. At the micro or community and household level, it concerns with whether the household members receive enough food, if the food distribution is adequate and whether the food is nutritious and can meet all the members' nutritional needs. Within the household, women and children are at higher risk of hunger.

To alleviate micronutrient deficiencies and improve food security, **food-based approaches** to dietary diversification can include:

- Increased production and market supply of micronutrient dense foods.
- Home garden projects
- Nutrition education, including processing/cooking methods that increase retention and bioavailability
- Subsidized food and income programs directed at the poor.
- Encouraging production of traditional food crops rich in micronutrients and improving the biodiversity of the food supply

Agricultural interventions focused on addressing malnutrition can have positive outcomes.

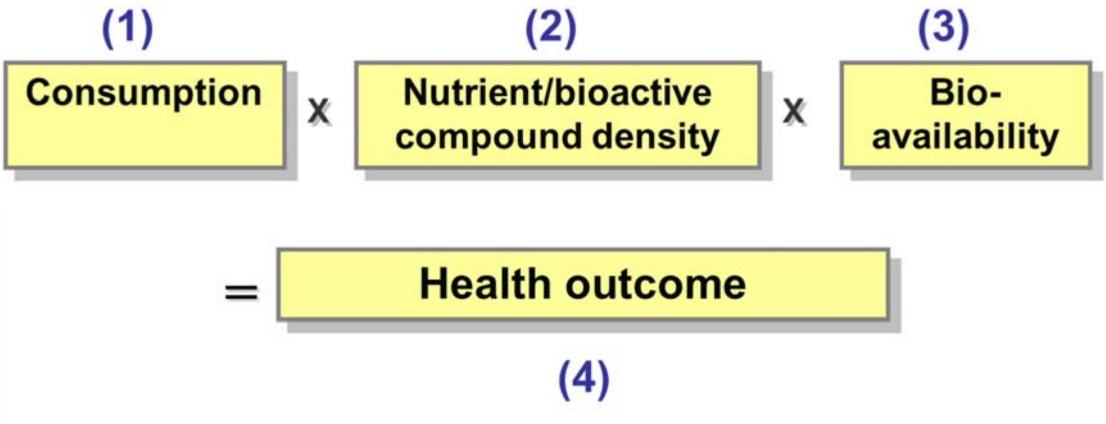
Agricultural interventions and nutritional outcomes

Number of studies with a positive effect on diet, anthropometrics, biochemical/ clinical indicator or morbidity (Berti, 2004)

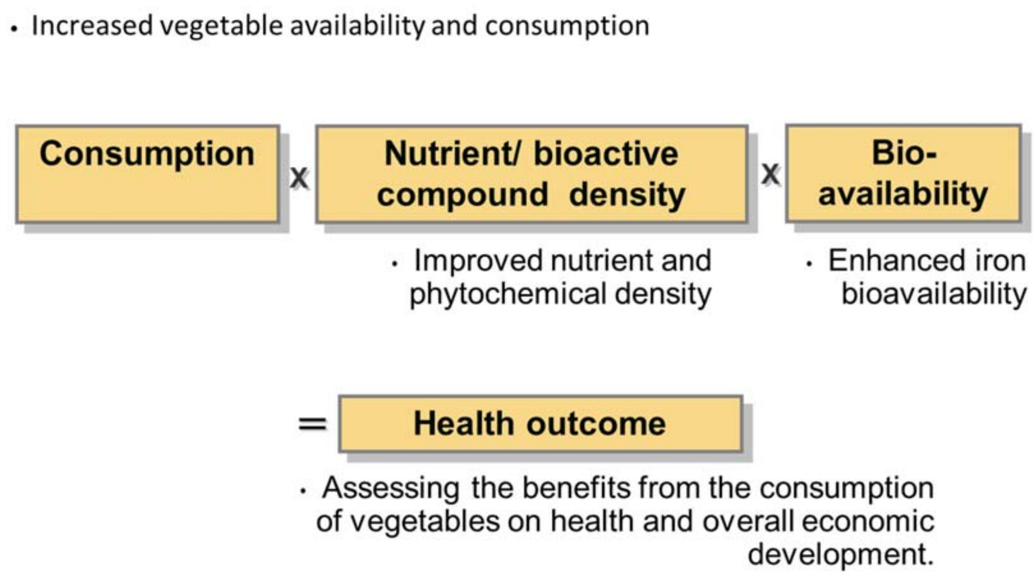
	Number of studies	Positive effect/total projects (negative effect)*			
		Diet	**Anthropo -metrics**	**Biochemical/ clinical indicators**	**Morbidity**
By type of intervention					
Vegetable/home garden	**9**	**9/9**	**3/3**	**2/4 (1)**	**2/3(1)**
Livestock	1	1/1			
Mixed livestock/gardening	0				
Cash cropping	5	2/3 (1)	2/5 (2)		0/2 (1)
Irrigation	2	1/1	0/2	1/2	1/2 (1)
Other	0				
Total	17	13/14 (1)	5/10 (2)	3/6 (1)	3/7 (3)
By 'improving nutrition' as explicit objective†					
Yes	**9**	**9/9**	**3/3**	**2/4 (1)**	**2/3 (1)**
No	8	4/5 (1)	2/7 (2)	1/2	1/4 (2)
By inclusion of nutrition education †					
Yes	**9**	**9/9**	**3/3**	**2/4 (1)**	**2/3(1)**
No	8	4/5 (1)	2/8 (2)	1/2	1/4 (2)

*When the outcomes were mixed (some aspects of the indicator were positive, some neutral, some negative), the indicator was scored negative if there were any negative aspects.
† The nine home gardening projects were the nine that had 'improving nutrition' as an explicit objective, and all nine included nutrition education.

Factors affecting the contribution of vegetable to improved health



AVRDC multi-strategies to improved nutrition and health



4.8 Nutrition indicators

Indicators and methodologies to address nutrition interventions

Components of indicators	Methodology
Socio-economic characteristics, food expenditure and market dependence	Household survey: questionnaire
Nutritional knowledge and awareness	Household survey: questionnaire
Crop and food diversity	Household survey: nutrient rich-crop in gardens, food diversity score (FDS) and dietary diversity score (FVS), number of food groups

Food consumption	Household survey: 24 hour diet recall or food frequency questionnaires for data of household dietary patterns, food intakes, and nutrient intakes
Anthropometry	Anthropometric measurements : • Adults: BMI for overweight and underweight • Children < 5: underweight (weight for age index), wasting (weight for height index), stunting (height for age index)
Biochemical data	Biochemical measurements: biological samples (urine or blood from human subjects) for nutritional status measurement such as anemia and retinol (vitamin A) levels
Other factors in food and nutrition security parameters	FAO suggested protocols Reference: B Maire and F Delpeuch, Nutrition Indicators for Development, Nutrition Planning, Assessment and Evaluation Service, Food and Nutrition, FAO (Rome 2005)

[a] level of evidence (I, II, II, IV) related to nutritional outcomes

4.9 School garden case studies

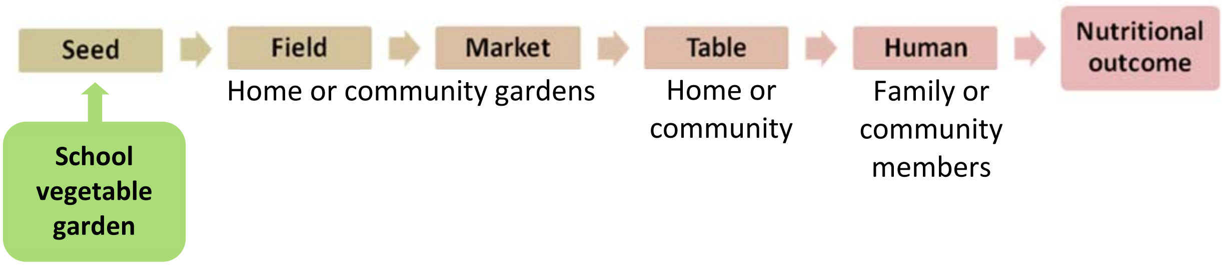
There is a currently a lack of evidence on the nutritional efficacy and effectiveness of school vegetable gardens for improving the diets and health of school children in developing countries. Testing the hypothesis that the nutritional security of school children will be improved in the target countries through school vegetable gardens, linked with other school-based health, nutrition and environmental initiatives with close participation of local communities, and that school vegetable gardens improve dietary diversity, nutrition and nutritional awareness in the target countries will be tested by determining if children at schools that follow the school vegetable garden approach have a greater awareness about nutrition, eat a more balanced and diverse diet, and have better nutritional outcomes than children at schools without school vegetable gardens.

Three case studies will be conducted, designed to understand the various roles of school vegetable gardens in the prevailing food systems, and the synergies with nutrition and health. Complementary public health research and nutrition related studies will be conducted by the Swiss Tropical and Public Health Institute and project partners to broaden the understanding of enabling factors (with particular attention to health, water, sanitation and hygiene at the level of the school, and also in households and communities). Depending on the country and specific location, the school children and their families may be exposed to major water-related diseases (e.g. diarrhea, malaria and schistosomiasis) and inappropriate food and nutrition practices that could jeopardize the nutritional benefits of producing and consuming vegetables. Assessments of children's dietary and health profiles at school and at household levels and regular cross-sectional surveys on some context specific food and health determinants will be implemented.

Disease prevention/control activities will be promoted in partnership with specific public health programs (e.g. with 'Roll Back Malaria' programs and national programs related to schistosomiasis and diarrhea wherever relevant) to increase the nutrition benefits from the project.

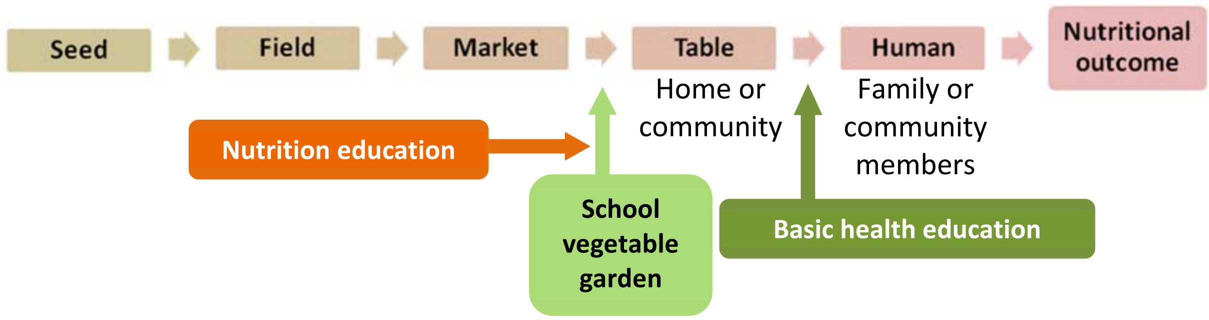
School vegetable gardens will produce food, but food production and its direct provision to students or communities is not the main objective for the school vegetable gardens. The major purpose of the school vegetable gardens is predominantly educational; vegetables produced from the garden can help supplement the school children's diet but the main impact of the project will be through changes in behavior and through increased dietary diversity as a result of the increased knowledge from the school vegetable gardens. Three scenarios will be explored through case studies to understand how school vegetable gardens can contribute to school children's nutritional outcomes. Each case study will be implemented in one selected country based on the national Action Plan. Detailed implementation and research protocols will be developed with national partners following local and international guidelines.

Scenario 1: School vegetable gardens to promote agricultural/horticultural skills and as a seed production and distribution system to enhance home and community garden vegetable production which leads to increased household consumption and improved nutrition. Seeds can be distributed to school children to take home and encourage their families and communities to plant vegetable gardens to improve their diets with the produce.

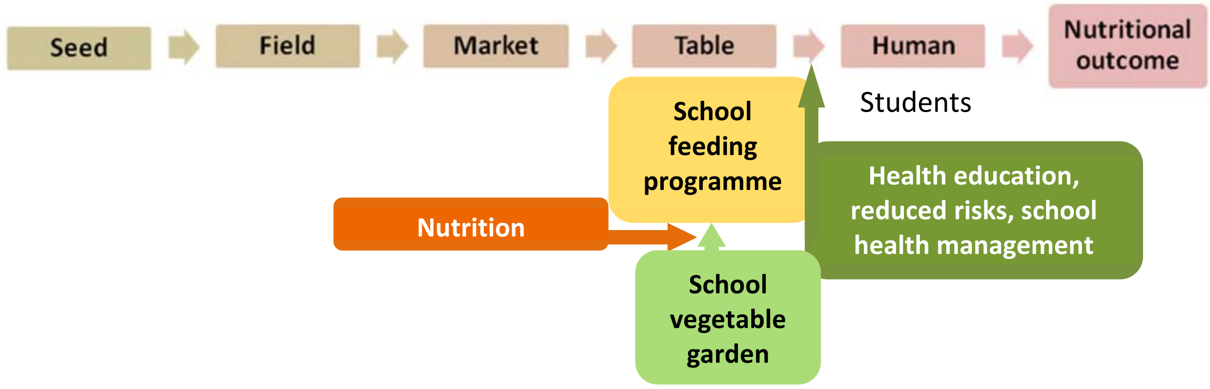


A case study to address Scenario 1 will be conducted in one selected country based on the national Action Plan and where home or community gardens are in place and access to, and availability of, quality vegetable seed is one of the main constraints. The research questions to be addressed are: a) whether school vegetable gardens, as a learning tool (without other complementary interventions), contribute to knowledge, behavioral change and nutritional outcomes, and to identify the enabling factors; and b) to understand if seeds made available from school vegetable gardens improve vegetable production and consumption in the home or community garden.

Scenario 2: School vegetable gardens as an educational and promotional tool to enhance healthy food choices, good nutrition and health practices. In this scenario, the school vegetable garden is an educational tool for teaching school children about nutrition and basic health (water, sanitation and hygiene). With increased knowledge and awareness, school children promote vegetable consumption, healthy eating and good health practices (sanitation) in their families and communities. The outcome is better nutritional status for family members including school children. The main research question to be addressed is whether school vegetable garden programs can be an effective educational tool for teaching school children about nutrition and basic health (water, sanitation and hygiene).



Scenario 3: School vegetable gardens as a school feeding program provider and educational tool to enhance healthy eating and improve the nutritional status of school children. The school vegetable gardens can provide one, or sometimes two, portions of vegetables for the school children if schools offer feeding programs. The direct beneficiaries will thus be the children whose diets are supplemented through meals taken at school. To sustain this scenario, schools will need to invest in school kitchens and the preparation of school meals and to maintain the school vegetable garden to ensure a regular supply of vegetable produce to maintain the nutritional quality of the meals. The research question for this scenario is to understand whether school vegetable garden programs that are linked to school feeding programs are more effective in contributing to knowledge, behavioral change and nutritional outcomes in school girls and boys than school vegetable garden programs without such link.



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5 School Vegetable Garden and Synergies with Water, Sanitation, Hygiene and Health

Guéladio Cissé

Swiss Tropical and Public Health Institute, Basel, Switzerland

Wednesday 4 September

5.1 Water, Sanitation, Hygiene and Health (WASH)

5.1.1 General concepts and glossary of WASH core terms

The VGTS project and the training of trainers' workshop will involve individuals from different background and disciplines. It is therefore important to start by clarifying some terms, to bring everybody at the same level of understanding of the sectorial jargons.

We start with the term WASH. The acronym WASH became a generic term embracing not only Water, Sanitation and Hygiene (WASH) but also Health promotion. That's why there is no need to add a second H.

Here below are following a number of terms used by professionals working in WASH. The selection is somehow arbitrary. But it is just a basis. During the workshop any other relevant work may be put forth by the participants and efforts will be made in participatory manner for shared clarification and understanding of meanings.

Per alphabetical order (definitions taken from various sources like UNICEF, WHO, USAID):

Coliform bacteria: A bacterial indicator of the sanitary quality of food and water. This bacterium is abundant in faeces of warm-blooded animals and can be found in aquatic environments, in soil, and in vegetation. Coliforms may not be the cause of disease, but they can be easily cultured and may indicate that pathogens of faecal content are present.

Diarrhea: Diarrhea is the passage of 3 or more loose or liquid stools per day, or more frequently than is normal for the individual. It is usually a symptom of gastrointestinal infection, which can be caused by a variety of bacterial, viral and parasitic organisms. Infection is spread through contaminated food or drinking-water, or from person to person as a result of poor hygiene.

E. coli: *Escherichia coli* are rod-shaped Gram negative bacteria named after its discoverer Theodore Escherich. A type of coliform bacteria, E. coli is commonly found in the lower intestine of warm-blooded animals and comprises about 1 per cent of the total faecal bacterial flora of humans. Sewage is likely to contain E. coli in relatively large numbers. As an indicator organism, its value is enhanced by the ease with which it can be detected and cultured.

Fecal Coliform: Bacteria found in the intestinal tracts of warm-blooded animals. The presence of high numbers of fecal coliform bacteria in a water body can indicate the recent release of untreated sewage and/or the presence of animal feces. These organisms may also indicate the presence of pathogens that are harmful to humans.

Health promotion: the art and science of helping people change their lifestyle to move toward a state of optimal health.

Health system: consists of all organizations, people and actions whose primary intent is to promote, restore or maintain health.

Health: a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.

Hygiene promotion: a planned approach for preventing diarrheal diseases through the widespread adoption of safe hygiene practices. It is built on and starts with what local people know, do and want.

Hygiene: The collection of behaviours relating to safe management of excreta, such as washing hands and disposing safely of household wastewater. Together with sanitation, hygienic behaviour is critical for control of diarrheal diseases and parasitic infections that cost lives and contribute to malnutrition.

Parasitic infection: contamination of one organism with another living organism that then begins to feed off or reside in the initial organism. When most humans have a parasitic infection they become ill, because their bodies are not supposed to play host to other large or small organisms of certain types, and these other organisms can cause destruction to the body including death if they are not somehow removed.

Pathogen: disease-causing biological agent such as a bacterium, virus, or fungus.

Potable Water: water that is safe and palatable for human consumption.

Safe Water Chain: The transmission of water-borne disease is minimized when the links of the "safe-water chain" are preserved.

Sanitation: Sanitation is the management and disposal of solid wastes and waste water in and around communities and households. The most dangerous waste product – and thus the focus of sanitation programmes – is human faeces.

Schistosomiasis : Schistosomiasis, also known as bilharziasis or snail fever, is a primarily tropical parasitic disease caused by the larvae of one or more of five types of flatworms or blood flukes known as schistosomes. The name bilharziasis comes from Theodor Bilharz, a German pathologist, who identified the worms in 1851. All five species are contracted in the same way, through direct contact with fresh water infested with the free-living form of the parasite known as cercariae. Eggs are excreted in human urine and feces and found in areas with poor sanitation, contaminate freshwater sources.

Soil-transmitted helminthic infections: Soil-transmitted helminthic infections are among the most common infections worldwide and affect the poorest and most deprived communities. They are transmitted by eggs present in human faeces which in turn contaminate soil in areas where sanitation is poor. The main species that infect people are the roundworm (*Ascaris lumbricoides*), the whipworm (*Trichuris trichiura*) and the hookworms (*Necator americanus* and *Ancylostoma duodenale)*. Humans become infected when ingesting infected eggs (*Ascaris lumbricoides* and *Trichuris trichiura*) or larvae (*Ancylostoma duodenal*e) in contaminated food (e.g. vegetables that are not carefully cooked, washed or peeled), hands or utensils or through penetration of the skin by infective hookworm larvae in contaminated soil (*Necator americanus* and *Ancylostoma duodenale*).

Thermo tolerant coliforms: Coliform bacteria that can multiply at certain temperatures. Because some coliforms such as E. coli can be found in the lower intestines of humans, optimal temperature for growth is 37.5 degrees Celsius.

Water Quality Criteria: levels of water quality expected to render a body of water suitable for its designated use. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, fish production, or industrial uses.

Water Quality Standards: ambient standards for water bodies adopted by the EMC and approved by the EPA that prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses. Water quality standards may apply to dissolved oxygen, heavy metals, pH, and other water constituents.

Water Quality: describes the condition of the water, including chemical, physical, and biological characteristics, usually with respect to its suitability for a particular purpose such as drinking or swimming.

Water Sources: There are three main sources of drinking water: groundwater, surface water, and rainwater. Depending on local geography, topography, climate, and needs, each of these may require different technologies and different levels of treatment in order to ensure the water is clean and accessible.

Water Treatment: The purpose of water treatment is to remove substances which may be dangerous to human health, such as pathogens (disease causing microbes) or other sources of contamination such as excess minerals or toxic substances.

Water Use: The number of litres of water used per person; including water for drinking, cooking, cleaning, sanitation and other uses. The average person's water use in the USA is 595 L/day, whereas in Ethiopia it is only 5 L/day.

Water: is very often used to refer to a topic involving a broad spectrum of issues, incorporating water supply, household water, sanitation and hygiene.

5.1.2 WASH at School

A school to be acknowledged with adequate WASH should have a functional and reliable water system that provides sufficient water for all the school's needs, especially for hand washing and drinking (WHO 2009). The school must also have a sufficient number of toilet facilities for students and teachers that are private, safe, and clean and gender segregated.

The school should have several hand washing facilities, including some that are close to toilets to facilitate hand washing after defecation. Facilities should cater to the needs of the entire student body, including small children, girls of menstruation age and children with disabilities.

Schools with poor water, sanitation and hygiene conditions, and intense levels of person-to-person contact, are high-risk environments for children and staff, and exacerbate children's particular susceptibility to environmental health hazards.

Children's ability to learn may be affected by inadequate water, sanitation and hygiene conditions in several ways. These include helminthic infections (which affect hundreds of millions of school-age children), long-term exposure to chemical contaminants in water (e.g. lead and arsenic), diarrhoeal diseases and malaria infections, all of which force many schoolchildren to be absent from school. Poor environmental conditions in the classroom can also make both teaching and learning very difficult.

WASH in schools may include water supply (water quality, quantity and access), hygiene promotion, sanitation (quality and access), control of vector-borne disease, cleaning and waste disposal, and food storage and preparation. The word "school" includes primary and secondary schools, boarding and day schools, rural and urban schools, and public and private schools.

Children who have adequate water, sanitation and hygiene conditions at school are more able to integrate hygiene education into their daily lives, and can be effective messengers and agents for change in their families and the wider community. Conversely, communities in which schoolchildren are exposed to disease risk because of inadequate water supply, sanitation and hygiene at school are themselves more at risk.

The hygiene behaviours that children learn at school — made possible through a combination of hygiene education and suitable water, sanitation and hygiene-enabling facilities — are skills that they are likely to maintain as adults and pass on to their own children.

There are some essential measures that are required to protect health in schools (WHO 2009):

- Provide basic sanitation facilities (with separate facilities for boys and girls) that enable schoolchildren and staff to go to the toilet without contaminating the school grounds or resources such as water supplies. This may entail measures as basic as digging temporary pit toilets, or defining separate defecation and urination areas outside the school, and rotating those areas to avoid a rapid build-up of contamination. Note: the risk of transmission of soil-based helminths increases with the use of defecation fields. Use of shoes or sandals helps to provide protection from hookworm infections.
- Provide water and soap (or ash) for hand washing after going to the toilet and before handling food. This may be achieved using simple and economical equipment, such as a pitcher of water and a basin.
- Provide safe drinking-water from a protected groundwater source (spring, well or borehole), or from a treated supply, and keep it safe until it is drunk. Untreated water from unprotected sources can be made safer by simple means such as boiling or filtering, or by using simple household water treatment systems (e.g. locally available chlorine solution). Schoolchildren and staff may have to bring water from home if the school does not have a safe water source nearby.
- Fence the school grounds so that a clean environment can be maintained. Fencing may be made cheaply with local materials.
- Plan and implement improvements so that adequate conditions for the long term can be achieved as soon as possible.
- Promote hygiene to increase children’s understanding of the importance of hygiene and a clean school environment.

5.2 WASH and Nutrition linkages

5.2.1 Evidence on health impact of WASH

Diseases related to inadequate water, sanitation and hygiene are a huge burden in developing countries (UNICEF 2009). It is estimated that 88% of diarrhoeal disease is caused by unsafe water supply, and inadequate sanitation and hygiene.

The environment influences the health of people in many ways – through exposures to various physical, chemical and biological risk factors. There are five environmental exposures when quantified together account for nearly 10% of deaths and disease burden globally and around one quarter of deaths and disease burden in children less than 5 years of age (WHO 2004). These are: (i) Unsafe water, sanitation and hygiene; (ii) Urban outdoor air pollution; (iii) Indoor smoke from solid fuels; (iv) Lead exposure; (v) Climate change.

In 2004 (WHO 2009), the leading global risks for mortality in the world are high blood pressure (responsible for 13% of deaths globally), tobacco use (9%), high blood glucose (6%), physical inactivity (6%), and overweight and obesity (5%). They affect countries across all income groups: high, middle and low. The leading global risks for burden of disease as measured in disability-adjusted life years (DALYs) are underweight (6% of global DALYs) and unsafe sex (5%), followed by alcohol use (5%) and unsafe water, sanitation and hygiene (4%).

A total of 10.4 million children died in 2004, mostly in low- and middle-income countries. An estimated 39% of these deaths (4.1 million) were caused by micronutrient deficiencies, underweight, suboptimal breastfeeding and preventable environmental risks. Most of these preventable deaths occurred in the WHO African Region (39%) and the South-East Asia Region (43%).

In 2004, 83% of the world's population had some form of improved water supply, while 59% (3.8 billion) had access to basic sanitation facilities. Most diarrhoeal deaths in the world (88%) are caused by unsafe water, sanitation or hygiene. Overall, more than 99% of these deaths are in developing countries, and around 84% of them occur in children

Many diseases are caused by more than one risk factor, and thus may be prevented by reducing any of the risk factors responsible for them. As a result, the sum of the mortality or burden of disease attributable to each of the risk factors separately is often more than the combined mortality and burden of disease attributable to the groups of these risk factors.

In 2004, 10.4 million children under 5 years of age died: 45% in the WHO African Region and 30% in the South-East Asia Region. The leading causes of death among children fewer than 5 years of age are acute respiratory infections and diarrhoeal diseases, which are also the leading overall causes of loss of healthy life years. Child underweight is the leading individual risk for child deaths and loss of healthy life years, causing 21% of deaths and DALYs. Child underweight, together with micronutrient deficiencies and suboptimal breastfeeding, accounted for 35% of child deaths and 32% of loss of healthy life years worldwide. Unsafe water, sanitation and hygiene, together with indoor smoke from solid fuels, cause 23% of child deaths.

For example, of all infectious and parasitic child deaths (including those caused by acute lower respiratory infections), 34% can be attributed to underweight; 26% to unsafe water, hygiene and sanitation; and 15% to smoke from indoor use of solid fuels. Insufficient intake of fruit and vegetables is estimated to cause around 14% of gastrointestinal cancer deaths, about 11% of ischemic heart disease deaths and about 9% of stroke deaths worldwide.

Parasitic diseases still pose major obstacles to healthy growth and socio-economic development in developing countries. The greatest chance of getting parasitic infections tends to occur in underdeveloped countries, where methods of keeping the water supply free from amoeba or large parasites may not be as advanced. Certain parts of the world run much greater risk for people getting parasitic infections than do others, and these include parts of Asia, Africa and South America.

Particularly, soil transmitted helminthiasis, including roundworm; hookworm and whipworm, are very common in children below the age of 15. Survey of Ghanaian primary school children revealed that as high as 30-50% of them can be infected with *Ancylostoma duodenale*, 6-12 % with *Ascaris lumbricoides*, 2% with *Strongyloides stercoralis* and 2% with *Trichuris trichiura* in Ghana. In Burkina Faso for example, over 140,000 cases of intestinal helminths morbidity were registered at the health centers in 2001 of which close to 25,000 were children aged 5-14 years.

5.2.2 Synergies between WASH, schools gardens and nutrition

The FAO recently acknowledged that “agriculture interventions do not always contribute to positive nutritional outcomes” (FAO 2012). Recognition that growing more food is necessary but usually not sufficient to achieve good nutrition and health leads directly to hypothesis-building around what else might be required (Webb and Kennedy 2012).

The reviews of evidence of agriculture-nutrition-health linkages of the past decade have concluded that too many studies rely on “simplistic associations” and too few “include all the necessary aspects of the research chain” (Hawkes et al. 2012). Positive impacts of agriculture on nutrition are more likely where integration of multiple sectors of activity has been strong.

There is a strong linkage between malnutrition and infection by disease-causing organisms such as bacteria, viruses, and parasites (Brown 2003). On the one hand malnutrition impairs both the barrier protection and the immune functions, leading to further sensitivity to infection while, on the other hand, infection decrease nutritional uptake as the nutrients cannot be absorbed properly. This vicious circle is the cause of many childhood deaths.

The importance of mediating environmental factors has only recently been highlighted as relevant to nutrition. Some studies recently argued that germs in faeces can contribute significantly to child stunting (Spears 2013). This is partly due to diarrhoea (loss of nutrients) and partly to enteropathy (chronic changes in the gut biomes that impact the lining of the intestines which impairs nutrient absorption and function).

The nutrition benefits of a school vegetable garden program can be jeopardized if the school and household environment is not safe or if common major diseases are not controlled.

The health risks can come from the necessary inputs on the school vegetable garden plots (water, soil, crops, fertilizers), from the agricultural practices (irrigation techniques, behaviors) and from consumption of contaminated vegetables.

The success of a school vegetable garden program will therefore depend on the existing conditions regarding water, sanitation, hygiene and disease control at school and home. The environment must prevent the children’s exposure to risk of injury, also safe handling of food grown on the plots must be promoted, vegetables and foods must be kept free of pathogens and chemicals, a safe environment maintained for children, teachers and parents.

The project will link with complementary school-based projects of other donors, such as the Blue Schools initiative of the Swiss Agency for Development and Cooperation (SDC) wherever possible.

In general, the objectives of a blue school are the following:

- Improving the health of children at schools and influence their environment at home. This would be achieved through the reduction of water borne diseases and worm infection and a cleaner environment.
- Raising awareness of children, teachers and parents about environmental and health issues related to water, sanitation, hygiene and nutrition through improving the teaching methods at schools, including the establishment of demonstrations and the link with the community level.
- Related goals are to protect the dignity of children, the effective learning of children, the enrolment and retention of children (especially girls) and to some extent a better diversified nutrition.

5.3 WASH component in VGTS project

5.3.1 Main areas of activities

The sustainability of the whole VGTS project will depend on many surrounding enabling environment and socio-cultural factors with a particular attention to health, water, sanitation and hygiene (not only at the level of the school but also at the levels of household and community).

Water: from many past experiences with vegetable gardens at school water is reported to be one of the major constraints for sustaining the project. The more sustainable water availability solutions in the respective contexts will be explored (e.g. rain harvesting, dug wells) and the quality of the water for production and for drinking purposes will be considered.

Sanitation and Hygiene: the benefits for school children of consuming vegetables can be jeopardized by lack of sanitation facilities in the school and bad hygiene behaviors at household and community levels. A component allowing the construction of sufficient latrines for boys, girls and teachers and the promotion of hand washing at both school and household levels will be envisaged.

Health: depending on the country and city specific location context the children and their families may be exposed to high risks of some major water related diseases (e.g. diarrhea, schistosomiasis, malaria) that could jeopardize the nutritional benefits of producing vegetables. A baseline assessment of the health profile at school and at household levels will be undertaken. Concrete diseases prevention activities will be implemented (e.g. partnership actions with Rock Back Malaria programs and national programs related to schistosomiasis and diarrhea wherever relevant). A regular monitoring of some context specific health indicators will be included.

Household and community: Past experiences highlight that the success of a school gardens project depend strongly on the awareness and support of the school children, teachers, parents/care takers and their communities including local authorities. This is also highly valid for the health promotion activities. The "health" component activities of the project will involve school children, teachers, parents/care takers, local authorities, health sector actors in the community, community based associations and NGOs. The set-up of relevant committees involving the different concerned stakeholders and considering their perceptions will be important. This dimension will ask for a social scientist involvement in the team.

Sustainability: additionally to the availability of water and other production needed assets, depending on the context, it will be important to take into account the potential hazards that could affect the school and the gardens (extreme climate change events like floods and droughts) and to promote the preparedness of the children and the communities to disasters risk reduction and management.

5.3.2 WASH Monitoring package

The WASH monitoring package will be integrated in the overall monitoring program of the project. In each of the 30 schools to be followed, respecting the sampling scheme as described in other parts of this document, a number of WASH indicators will be selected. After a baseline evaluation the same indicators will be regularly measured at convened periods.

We will take reference from the main monitoring package information used in general by international organizations (UNICEF 2011). Nevertheless it is with the local partners that the final list of indicators and parameters will be established as well as the appropriate tools and approaches for the measurements and the data collection.

As indicative the following information will be collected:

School Information: school name, school identification code, school location (district/province/ other), school level (primary/middle/secondary/mixed/ other), school area (urban/rural), school management (public/private/religious institution-managed), school type (day school/boarding school/other), student population (no. of boys, no. of girls, total)(questionnaire designer to decide exactly, which number to use depending on country norms: e.g. average over the year, net, etc.), no. of shifts (if applicable: if the school is operated in shifts, student population should be higher number of the two shifts), students with physical disabilities (no. of boys, no. of girls, total), teachers (no. male teachers, no. of female teachers, total), does the school have a Parent Teachers Association (PTA)?, does the school have some other formal institutional link with the community or other parent/community organizations?

(e.g. management committee), does the school have student led organizations? Do they play any role in supporting WASH in Schools?

First indicative list of main indicators to monitor may be the followings:

- **Water Indicator:** A functional water point is available at or near the school that provides a sufficient quantity of water for the needs of school, is safe for drinking, and is accessible to children with disabilities.
- **Sanitation Indicator:** The number of functional toilets and urinals for girls, boys and teachers meet national standards, and are accessible to children with disabilities.
- **Hygiene Indicator:** Functional hand washing facilities and soap (or ash) are available for girls and boys in the school, and hygiene is taught.
- **Waste Disposal Indicator**: Solid waste and sludge are regularly and appropriately disposed.
- **Parasitic infections indicator:** Level of infections is reduced.

The detailed WASH monitoring package and plans will be finalized with the partners.

5.3.3 Case studies design

The project will test the hypothesis that the nutritional security of school children will be improved in the target countries through school vegetable gardens, linked with other school-based health, nutrition and environmental initiatives with close participation of local communities. It will also consider that school vegetable gardens improve dietary diversity, nutrition and nutritional awareness in the target countries will be tested by determining if children at schools that follow the school vegetable garden approach have a greater awareness about nutrition, eat a more balanced and diverse diet, and have better nutritional outcomes than children at schools without school vegetable gardens.

Three case studies will be conducted, designed to understand the various roles of school vegetable gardens in the prevailing food systems, and the synergies with nutrition and health. Three scenarios will be explored through case studies to understand how school vegetable gardens can contribute to school children's nutritional outcomes. Each case study will be implemented in one selected country based on the national Action Plan. Detailed implementation and research protocols will be developed with national partners following local and international guidelines.

5.4 Short indicative bibliography

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6 Communication strategies for school vegetable gardens

Maureen Mecozzi

AVRDC-The World Vegetable Center

Tuesday 27 August

A good communication strategy is built around three simple concepts:

- GOAL: *What you want to achieve*
- GROUP: *The people you need to reach*
- GAIN: *The information that will benefit/meet the needs of those people*

Numerous tools and techniques can be used to stimulate people's awareness, participation and capabilities, but there is no one combination of messages and methods that can guarantee success. Just keep these concepts in mind as you develop strategies to promote your school garden, and you'll be well on the way to engaging the interest of your audience.

6.1 To set a goal, begin at the end

Picture your ideal school garden at the peak of vegetable production: It is a beautiful and attractive green addition to your school grounds, where students actively enjoy learning about growing plants, producing food and improving health. Focus on that picture and develop a brief goal statement: *Our students will grow and thrive in the District #3 Primary School Vegetable Garden,* for instance, or *The school garden will enhance the our students' health and knowledge*. Let the goal direct all your communication actions related to the garden effort. You can then begin to develop specific approaches for different audiences.

6.2 A-U-D-I-E-N-C-E

In your school garden project, you will likely want to share information with several different groups of stakeholders, or target audiences. Your messages about gardening and nutrition will differ, depending on your audience. Consider their perspective. What might some of their perceptions or concerns be about a school garden? What kind of information will they need to create, maintain and promote a garden—and eat more vegetables? How do they prefer to receive information? Follow your A-U-D-I-E-N-C-E:

- ***A***nalysis: Who do you want to reach?
- ***U***nderstanding: What is the audience's knowledge of the subject?
- ***D***emographics: What is their age, gender, education background, etc.?
- ***I***nterest: Why would they want to listen to, watch or read your message?
- ***E***nvironment: Where will this message be shared or seen?
- ***N***eeds: What are the audience's needs associated with the subject?
- ***C***ustomization: What needs/interests should you address for a specific audience?
- ***E***xpectations: What does the audience expect to learn?

A school garden project would typically have four main audiences:

- **Students:** Expect plenty of questions! Students will want to know why the school is creating a garden, why they are being asked to participate, how much effort and time will be required from them, and what they will get out of gardening (A grade? Fresh vegetables? Lunch? A chance to have fun with their friends outdoors?). Create a sense of camaraderie and ownership around the garden, and students will begin to identify it as an inclusive but special activity—one they will want to join.
- **Parents:** They need assurance that the garden activity will benefit their child and will not detract from other "more important" subjects. They may want to know how the harvest will be used: consumed in the school canteen, or perhaps sold for extra school income. Explain why their children's body measurements are being taken. Parents can learn from their children; consider how you can help your young school gardeners "bring lessons home" to engage their parents.
- **Colleagues:** Your fellow teachers, school administrators, and ministry officials are key audiences for support and advice. Keep them informed about the progress of your school garden. Seek their input and look for ways to use the garden to connect colleagues across disciplines.
- **Community:** People living in the village or neighborhood around the school may be curious about this new school activity. Build on that interest or spark it by inviting the public to join your school's effort to improve nutrition and health. Consult representatives from local government, health clinics, food markets, nongovernmental and other community organizations; they may be willing to provide expertise to extend the garden as a community learning tool.

These are the main audiences you will likely engage when communicating about your school garden, but there may be others, depending on your situation. Often the media is considered a separate target audience. Local media (radio, TV, newspapers) can help spread your message if you provide them with fresh, interesting and timely information; global media (web/social media) can extend your garden activities to the world. Include the media in your communication strategies—but be aware that focusing a lot of effort on obtaining media coverage may not always help you achieve your goal, and may absorb resources that could have been put toward communicating with other key audiences.

6.3 Stakeholder communication strategy chart

Use this chart to help plan your school garden communication strategy:

Audience *[Name and needs]*	Goal *[What should the message achieve?]*	Message *[What is the message?]*	Method *[How will the message be conveyed?]*	Timing *[When will the message start and end?]*	Who's responsible? *[Who will carry out the communication effort?]*	Cost

6.4 Awareness

There are many methods and tools you can use to create awareness and generate interest about your school garden. Here are a few:

- Hold a special event to launch the garden: Invite local dignitaries, parents and farmers to join the students in a ribbon-cutting ceremony. Let them plant some seeds or seedlings with the students. Take photos and post them around the school. Contact the local newspaper or radio station. Remember the global community, too: Be sure to share your pictures with the Vegetables Go to School Web/GIS Platform.
- Let the whole school know who's involved! Provide your garden team with special hats, ribbons, pins, T-shirts, vests, scarves or some other item to create an identity.
- Garden mascot: Engage students in creating a colorful and fun character as a symbol for the garden. Use the mascot on signs. Make a mascot costume and ask a student to wear it at school events.
- Create a welcome sign for the garden.
- Let the students research and prepare signs to identify different vegetable crops in the garden. Ask them to note why particular vegetables are good for health—for instance, vitamin A benefits eyesight.
- Offer garden updates during regular school announcements. Mention the vegetables that are in season. Be sure to say why vegetables are good and important to eat -- use the opportunity to talk about nutrition.

- If school garden vegetables are served in the school canteen, put signs next to the food so students know where their food is coming from, and who was responsible for growing it.
- Garden tours: Encourage participating students to guide their peers around the garden, explain what is growing, and talk about how vegetables are good for health and a garden can be good for the environment. Offer special student-guided tours for parents and other community members.
- Invite local farmers to inspect the garden or teach a specific gardening method to students.
- Invite a well-known local food stall owner, cook or chef to come to your school and demonstrate how to prepare healthy vegetable dishes using vegetables from the school garden. Ask them to prepare a traditional dish—*momo* in Nepal, for instance—by using different vegetables, or substituting vegetables for meat.
- Find out if there are famous people in your country, such as singers, TV stars or sports figures, who enjoy gardening or who promote healthy lifestyles. Invite them to your garden (you never know, they might come!) or ask for a signed photo with a message promoting gardening and health that you can post in the school.
- Gado Gado Garden: Select a favorite national recipe—*gado gado* in Indonesia, for instance —and grow the vegetables needed for the dish together the same section of the garden.
- Organoleptic testing: Invite parents and community representatives to join students in evaluating their vegetable crops for taste and appearance. Pass out ranking sheets and let students compile the data to share with participants.

6.5 Incentives

Healthy competition lends excitement and fun to everyday activities. Set some challenges based on garden activities and watch students rise to the occasion:

- Cooking competition: Let different groups of students prepare simple vegetable dishes for a classroom snack. Everyone samples the food and votes for their favorite vegetable dish. The winners get their recipes published in a pamphlet.
- Grow big: Give student gardeners a chance to nurture some big crops. Measure the fruit by size or weight. Put the biggest vegetables on display for all to see, and award the growers with certificates or other acknowledgement.
- Art show: Involve students in sketching the garden and some of the individual plants. Post their drawings around the school in a special display.
- Music: Encourage musically inclined students to write and sing a song inspired by the school vegetable garden. Let them perform the song during a school assembly. Record it on video, if possible, and post it on YouTube.

7 What is the impact of our school vegetable garden?

Pepijn Schreinemachers

AVRDC-The World Vegetable Center

Wednesday 28 August

Giving children the means to grow their own food while simultaneously raising their awareness of the importance of a diversified diet will allow them to take better decisions about their own nutrition while also improving their resilience against food shortages. Although this idea is compelling, the scientific evidence for nutritional benefits of school gardens is poor. Most previous studies are for the United States only, used very small samples of schools, and did not use robust scientific methods. One of the objectives of the Vegetables Go to School project is therefore to address this shortcoming by doing a robust assessment of the short-term impacts of school vegetable gardens. We expect that if we can show the impact of school vegetable gardens using scientifically sound methods, then this will much increase the interest of local governments as well as international donor organizations to support the scaling-out of school garden programs.

7.1 Study design

To assess the nutritional outcomes of school vegetable gardens in this Phase I of the project, a randomized controlled trial (RCT) design will be used. An RCT is a type of experimental study design in which subjects (schools in our case) are randomly selected from a larger eligible population of schools for inclusion in our project and then randomly assigned to either the intervention group (which will receive a school vegetable garden) or the non-intervention group (which will not receive a school vegetable garden). Randomization is essentially like tossing a coin to determine in which group a school is allocated.

The importance of randomization is that ensures that schools are representative for a larger population of schools and that allocation (or selection) bias is minimized, as illustrated in Figure 1. If subjective criteria are used in the school selection then it is likely that project schools would have certain favorable conditions that would make them particularly suitable for establishing school vegetable gardens. Although this has the potential of showing success, it would be impossible to prove the level of success, as there would be no valid counterfactual for comparison.

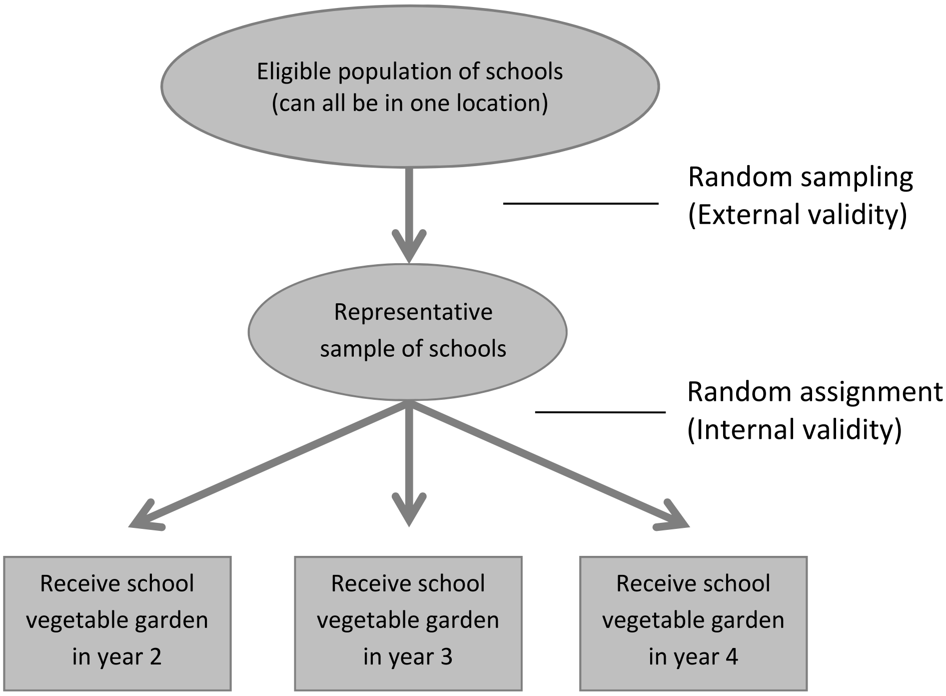

Figure 1 Internal and external validity in a randomized controlled trial

The random selection of schools does not mean that we take a sample from all schools in the country. The variation between schools would be too large to do a meaningful comparison and the small sample of schools could never be representative for all schools in the country. Instead, schools have to be selected from a smaller population of schools using strict eligibility criteria that reduce the variation between schools. These eligibility criteria could be any of the following:

1. **Type of schools:**
    - Elementary or secondary school [1]
    - Private or public schools
    - Boys schools, girls schools or mixed schools [2]
2. **Location of the schools:**

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[1] Studies have shown that children who consume more fruit and vegetables in childhood also consume more fruits and vegetables as adults (Heimendinger and van Duyn 1995). This is one of several reasons why most school garden programs have targeted elementary school children.

[2] Lineberger and Zajicek (2000) found for a case study in the US that school girls were more receptive to health and nutritional education related to school gardens, presumably because the girls were more concerned about their physical appearance than the boys.

- Schools in those areas where nutrition is known to be a problem
- Urban, peri-urban or rural areas
- Schools in upland or lowland areas

3. **Practical and strategic selection criteria:**
    - Particular district(s) to facilitate the logistics and monitoring of the project
    - Schools must have a minimum amount of suitable land available
    - Schools must have access to water for irrigation
    - Links to SDC's Blue Schools program (without proper hygiene and sanitation, school gardens might not improve nutrition)

After applying these criteria there should be a total population of schools of about one hundred. We note that strict eligibility criteria ensure a more meaningful comparison between schools (and hence improve the 'internal validity' of the study); yet, the drawback is that the generated evidence will only apply to a smaller group schools and cannot be generalized to all schools in the country (and hence reduce the 'external validity').

From the total population of eligible schools, a sample of 30 schools will be randomly selected to be included in the project. Each of these schools will receive a school vegetable garden from the project, but only at different times. Schools in the sample will be randomly allocated to three groups, which will receive the school vegetable garden in year 2, 3 and 4, respectively as shown in **Table 1**. In this type of roll-out design, future project schools are used as a counterfactual (or control) to measure the impact of the school vegetable gardens.

Table 1 Roll-out design of the randomized controlled trial, number of schools

Country	Year 2 (2014)		Year 3 (2015)		Year 4 (2016)	
	Intervention	Control	Intervention	Control	Intervention	Control
Bhutan	10	20	20	10	30	0
Nepal	10	20	20	10	30	0
Burkina Faso	10	20	20	10	30	0
Tanzania	10	20	20	10	30	0
Total	40	80	80	40	120	0

Note: Year 4 (part of phase II of the project) will not be used in the evaluation since there is no control group.

7.2 Outcome indicators

The impact of school vegetable gardens needs to be assessed relative to its objectives. These objectives are not necessarily the same for each country. In higher income countries, the objectives of school garden programs often include environmental, academic and social objectives (e.g. promoting the self-esteem of children) while nutritional objectives are less prominent. In lower income countries, on the other hand, the nutritional objective often tops the list, followed by academic and agricultural objectives (sustainable farming, promoting home gardens). Clearly defining the objectives of the school vegetable program is not just important for evaluating its impact but also for its design. If the objective of the garden is primarily educational, then a small garden with just a few seed beds will do.

Table 2 Stylized comparison of behavioral objectives of school garden programs in higher and lower income countries

Higher income countries	Lower income countries
Environmental	**Nutritional**
- Creating positive environmental attitudes (awareness, environmental stewards)	- Address malnutrition (if combined with school feeding programs)
- Creating environmental knowledge	- Increase fruit and vegetable consumption
- Greening of schoolyards	- Address child obesity
Academic	**Academic**
- Hands-on academic instruction on science, environment, and nutrition	- Hands-on academic instruction on nutrition, health, biology, mathematics and financial management [3]
	- Encourage student enrollment/reduce dropout
	- Enhance school performance through better nutrition
Social	**Agricultural**
- Self esteem	- Promote sustainable farming
- Sense of belonging	- Promote agricultural productivity
- Compassion	- Transfer good practices to children's homes (e.g. home gardens)
Nutritional	**Economic**
- Raise vegetable consumption	- Raise revenues for school activities
- Address child obesity	- Stimulate the resilience of children to economic hardship
Community	**Social behavior**
- Community partnerships	- Promote gender equality

Although nutritional objectives might top the list in lower income countries, it is important to note that the school vegetable garden in itself is not meant to supply the school with vegetables. The size of the garden required to feed several hundreds of children every day

[3] This embraces the idea that children learn best by doing.

would be too large and the production target would marginalize any of the other objectives for establishing a school vegetable garden. It is also important that the labor time for children has to be minimized as children must create a positive attitude towards gardening in order to learn from it.

Table 3 List of outcome indicators used in the study

Indicator	Explanation	Method (examples)
1. Opinions/ attitudes	Does the school vegetable garden create more positive attitude of school girls and boys about gardening and eating vegetables?	- Do the school girls and boys enjoy gardening?
2. Preferences	Does the school vegetable garden change the preferences of school girls and boys for eating (fruits and) vegetables?	- Food preference questionnaire in which children have to select between various healthy (e.g. an apple) and less healthy (e.g. candy bar) snack items. - Are school girls and boys willing to taste various vegetables and how do they rate its taste?
3. Awareness	Does the school vegetable garden raise awareness about health, nutrition and the environment?	- Can they associate health benefits with eating certain vegetables?
4. Knowledge	Does the school vegetable garden increase the knowledge of school girls and boys about gardening and vegetables?	- Can they identify various vegetables? - What do plants need to grow? - How to prepare different food items? - Can they differentiate between 'good' and 'bad' insects?
5. Vegetable consumption patterns	Is there a behavioral change in the quantity and the diversity of vegetable consumption?	- Food diaries (journals) recorded by the school girls and boys to record quantities and diversity of vegetables consumed at home.

6. Nutritional status	Does the school vegetable garden affect the physical development of children?	- Anthropometrics (and age) recorded by the school teacher:[4]
		  - Weight (kg)
		  - Standing height (cm)

[4] Note of caution: "The physical growth of schoolchildren aged six to nine years is the result of the interaction between environmental and genetic factors. [...] An accurate interpretation of anthropometric indices in adolescents is difficult because of the variability in patterns of growth and maturation. During adolescence, hormonal changes accelerate growth in height and as a result nutrient requirements are increased significantly above those in the childhood years." (FAO 2004)

- Waist circumference (cm)
- Head circumference (cm)

Once the objectives of the school vegetable garden have been defined, relevant outcome indicators can be identified.

Although nutritional objectives might top the list in lower income countries, it is important to note that the school vegetable garden in itself is not meant to supply the school with vegetables. The size of the garden required to feed several hundreds of children every day would be too large and the production target would marginalize any of the other objectives for establishing a school vegetable garden. It is also important that the labor time for children has to be minimized as children must create a positive attitude towards gardening in order to learn from it.

Table 3Table 3 provides a list of alternative indicators. The table has an implicit hierarchy. Lower level indicators such as attitudes and preferences are more easily influenced by the school vegetable garden than higher level indicators such as vegetable intake and especially health outcomes (as measured by anthropometrics). For these lower level indicators it should be easier to show an immediate impact of school vegetable gardens. Higher level indicators, on the other hand, are affected by many factors other than the school vegetable garden and some of these factors might constrain the effectiveness of the intervention. For instance, eating more vegetables does not lead to the expected nutritional outcomes under conditions of disease, poor hygiene and poor water quality.

7.3 Data collection protocol

The selection, implementation and data collection process is outlined below although these will have to be adapted to the needs and interests of each project country:

1. Eligibility criteria for selecting schools to participate in Phase I of the project. These criteria should identify a target population of around 100 schools.
2. Develop a list of the schools for each country that meet the criteria. This is the sampling frame; each school on the list has the same chance of being selected for participation in the project.
3. Take a random sample of 30 schools from this list; schools will be contacted through the Ministry of Education to request their participation in this project.
4. Collect the following data from these schools (the data structure will be discussed and agreed during the Training-of-Trainers course):

5. General data on the school (e.g. type of school, location, number of students and teachers, infrastructure, sanitation and hygiene, existence of school vegetable gardens, lunch patterns of the children, distance from home to school)
6. General data on the surrounding communities (e.g. location, land use, income sources, infrastructure, sanitation, food sources and diets, other geographic data)
7. Interview a random sample of 100 school girls and boys from various classes and collect data on the outcome indicators (**Table 3**). This will constitute the baseline.
8. If the school already has a school garden, collect data such as structure, size, species grown, production, access to water and ecological characteristics.
9. Randomly allocate the 30 schools to three groups: 10 schools for establishing pilot gardens in years 1 and 2 of the project; 10 schools for year 3, and further 10 schools for year 4 (Phase II; these schools will be the counterfactuals for the third year of Phase I).This roll-out design of the project intervention is illustrated in Table 5. Collect data from all 30 schools in year 1.
10. Establish 10 pilot school vegetable gardens (Group 1) at the start of the school year towards the end of project year 1 or the beginning of project year 2 in each country (see Table 3). Collect follow-up survey data from each of the 30 schools at the end of year 2.
11. Establish 10 Group 2 pilot school vegetable gardens around the start of project year 3. Collect follow-up survey data from each of the 30 schools at the end of year 3. Group 3 schools are the 'control' schools, but they will be included to develop school vegetable gardens in year 4 (Phase II) of the project.
12. Quantify the outcome indicators (**Table 3**).

7.4 Data analysis

The phased introduction of school vegetable gardens will provide the counterfactual data to correctly attribute any observed changes in outcomes to the establishment of school vegetable gardens. The following methods will be used to quantify any changes due to the establishment of school vegetable gardens:

1. The impact of the one-year old school vegetable gardens can be established by comparing the post-intervention surveys for group 1 in year 2 with the pre-intervention surveys for groups 2 and 3 in year 2.
2. The impact of the two-year old school vegetable gardens can be established by comparing the post-intervention surveys for group 1 in year 3 with the pre-intervention surveys for groups 3 year 3.
3. The pre-intervention surveys can be used for matching school children based on observable characteristics and then using statistical matching methods for establishing the impact of school vegetable gardens. This use of multiple methods will lend robustness to the results.

4. The analysis will take gender explicitly into account by testing if there is a significant difference in outcome indicators between the school girls and boys.
5. Data collection will be the responsibility of the local partners but the project team will support the data collection by developing tools and protocols. The project team will be responsible for the outcome evaluation of Phase I, but local partners will be closely involved in every stage and receive training in the use of randomized controlled trials so that they can continue this activity in Phase II of the project. All data and results of the analyses will be posted on a web platform for other schools and countries to share.

It is important to note that although the data analysis will be done at the level of school girls and boys, which gives a relatively large sample of children, the intervention took actually place at the level of the school, which is a relatively small sample. The clustering of children in schools needs to be considered in the analysis of the data. We note that most previous impact studies of school gardens have not done this.

8 Collaborative data management and data sharing

Axel Drescher, Rüdiger Glaser, Klaus Braun, Mark Hoschek, Dirk Riemann, Helmut Saurer, and Steffen Vogt

Albert-Ludwigs-Universität Freiburg

Thursday 5 September

8.1 Introduction: Benefits of using a Collaborative Research Environment

The central tool for data management and data sharing for the VGtS project is a collaborative research environment (CRE). A CRE is much more than just a database. It is a web based platform that allows for data collection, data analysis, data sharing, and data archiving by providing appropriate web based tools.

To support data management and data sharing in a large project, a CRE

- provides the same tools for all partners
- ensures a common data structure
- secures data management and archiving
- allows for sharing data between partners according to access rules the partners have agreed upon
- enables joint data analysis with standardized tools
- can be used for communication amongst project partners
- is a platform to disseminate project results

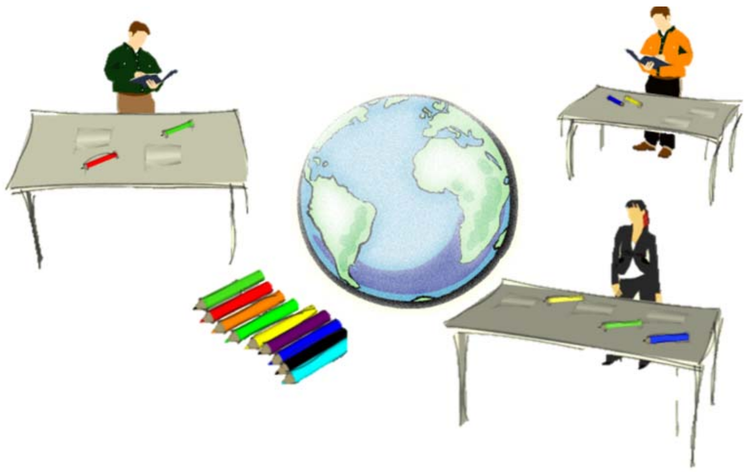

Figure 2 Typical challenge of a large project: different project teams work at different locations, different working hours, with different data formats and different tools.

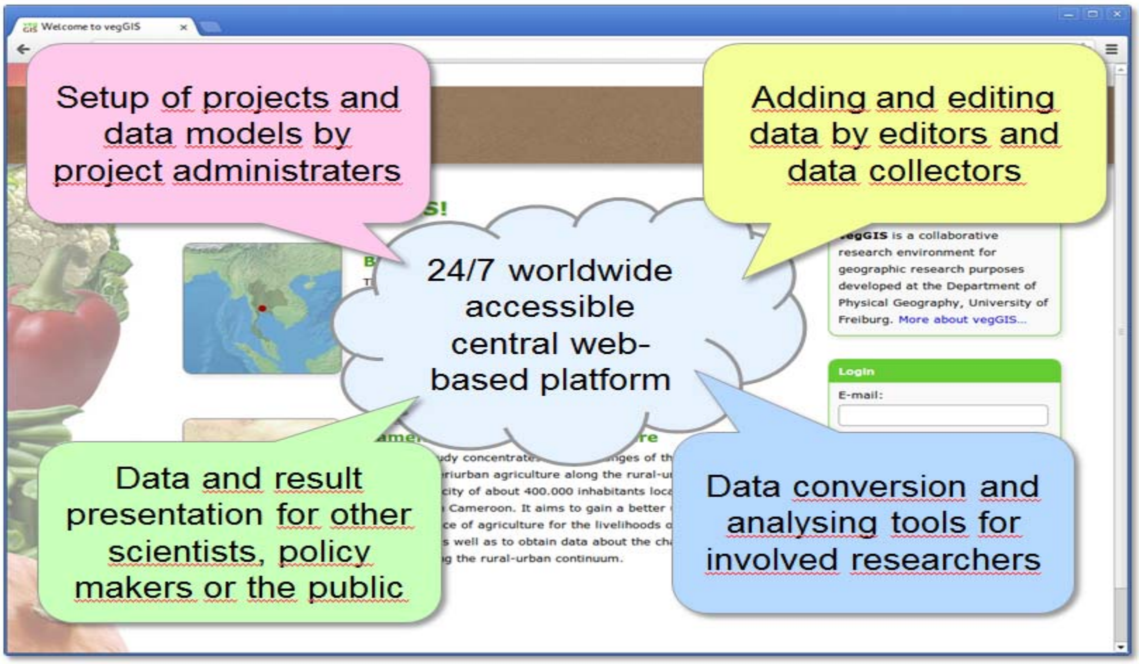

Figure 3 Functional aspects of a CRE

The CRE consists of

- User management
  Users can have different roles with different rights for different tasks (e.g. data manager, data editor, data analyst, assistant, visitor etc.)
- Project and Data management
  Setup of sub-projects and data models

- Data collection tools
  Online and offline forms derived from the data model (questionnaires, maps, data sheets)
- Visualization, communication and analysis tools
  Content management system to publish project information, results, maps, images, charts etc.
  Sharing best practices and capacity building knowledge
  Data export tools for further processing of the data

8.2 Data management of the project

Within the VGtS we can distinguish three different feature classes: we will basically work on the level of schools, school gardens, and school children. We have two application domains, in which these objects will be used (see fig. 1). One is the research domain, in which scientific assessments, project monitoring and project evaluation takes place.

The other application domain is the dissemination domain. This domain includes activities such as outreach for the project, capacity building for school gardeners, communication between schools / school children and the like.

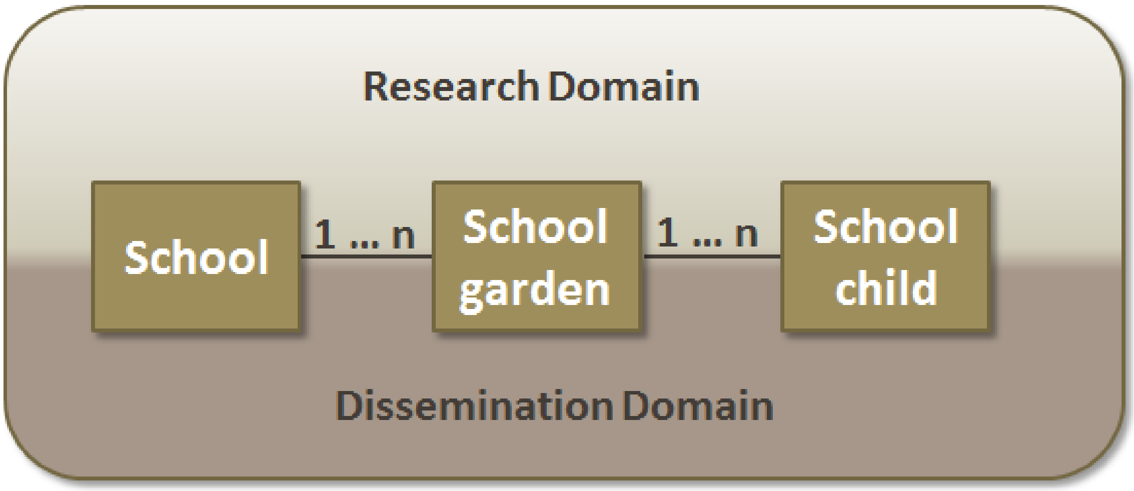

Figure 4 Simplified conceptual data model and application domains

At the start of the project we have to focus on the research domain in order to create a suitable data platform to support implementation of the project. When scaling the project to a large number of schools the dissemination domain becomes increasingly important.

Within the research domain the CRE has to support two essential work flows: data production and data consumption, i.e. quality controlled input and structured output of data.

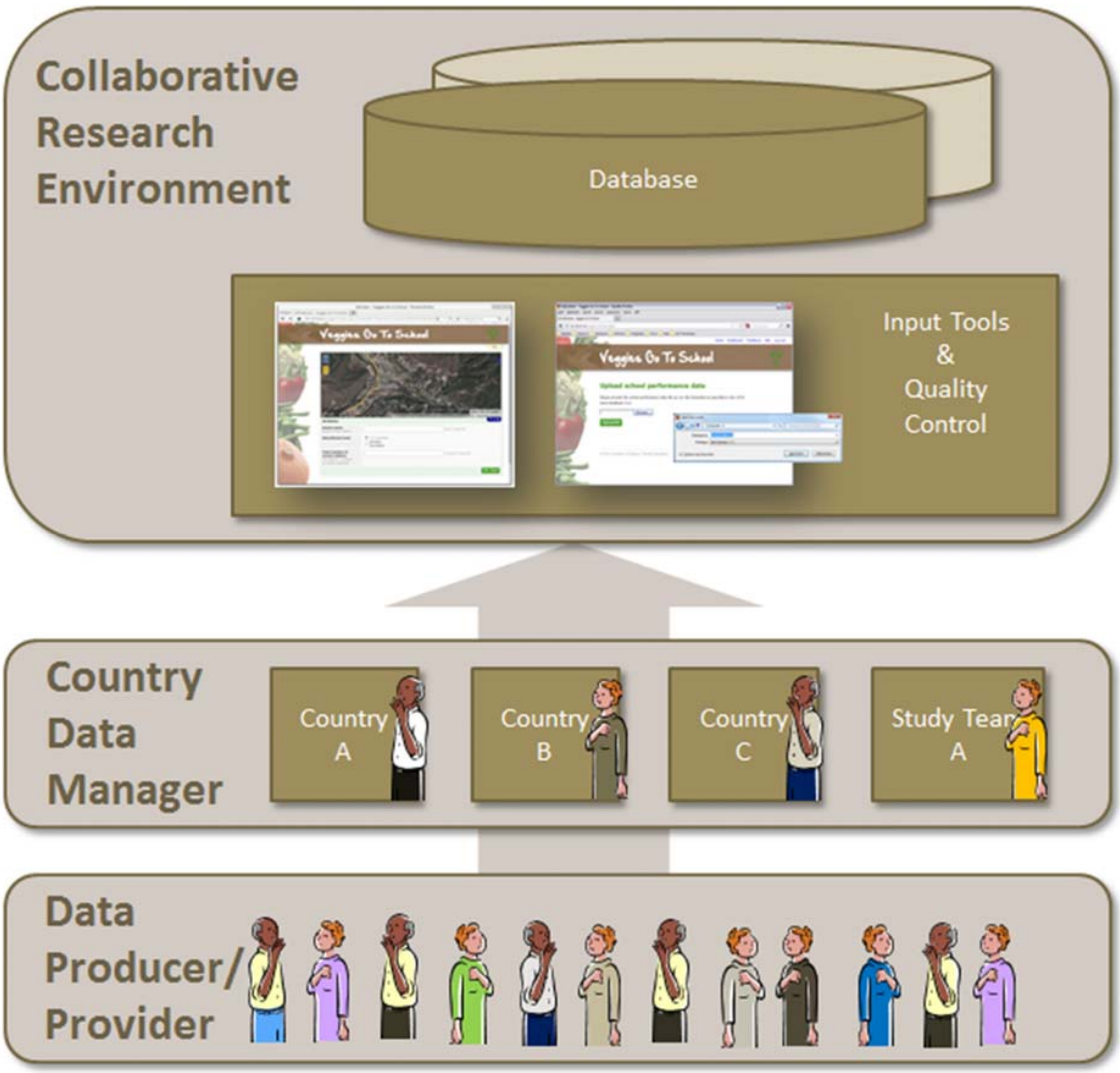

Figure 5 Input data workflow.

The CRE provides web based tools for online data entry or data upload, including quality control mechanisms. Country data managers supervise data input from individual data producers and are responsible contact persons to ensure a sustained data input flow for each country.

Data sharing and joint analysis of data is crucial to the success of the project. The CRE provides tools for data analysis and visualization, and also for data download for external applications. It is important to note that the CRE features advanced data access control mechanisms that implement the data access policy of the project. A specific user can see and/or edit only that portion of the data that the role he/she is assigned to allows.

The CRE alleviates the data management for individual data producers and countries substantially as data accessibility and data archiving is guaranteed by the CRE reducing data management costs for the project partners significantly. The web based CRE is available to all project partners. Consequently it is not required from the project partners to implement and maintain individual data management systems. It is important to note that the CRE also features a backup and recovery system minimizing the risk of data loss.

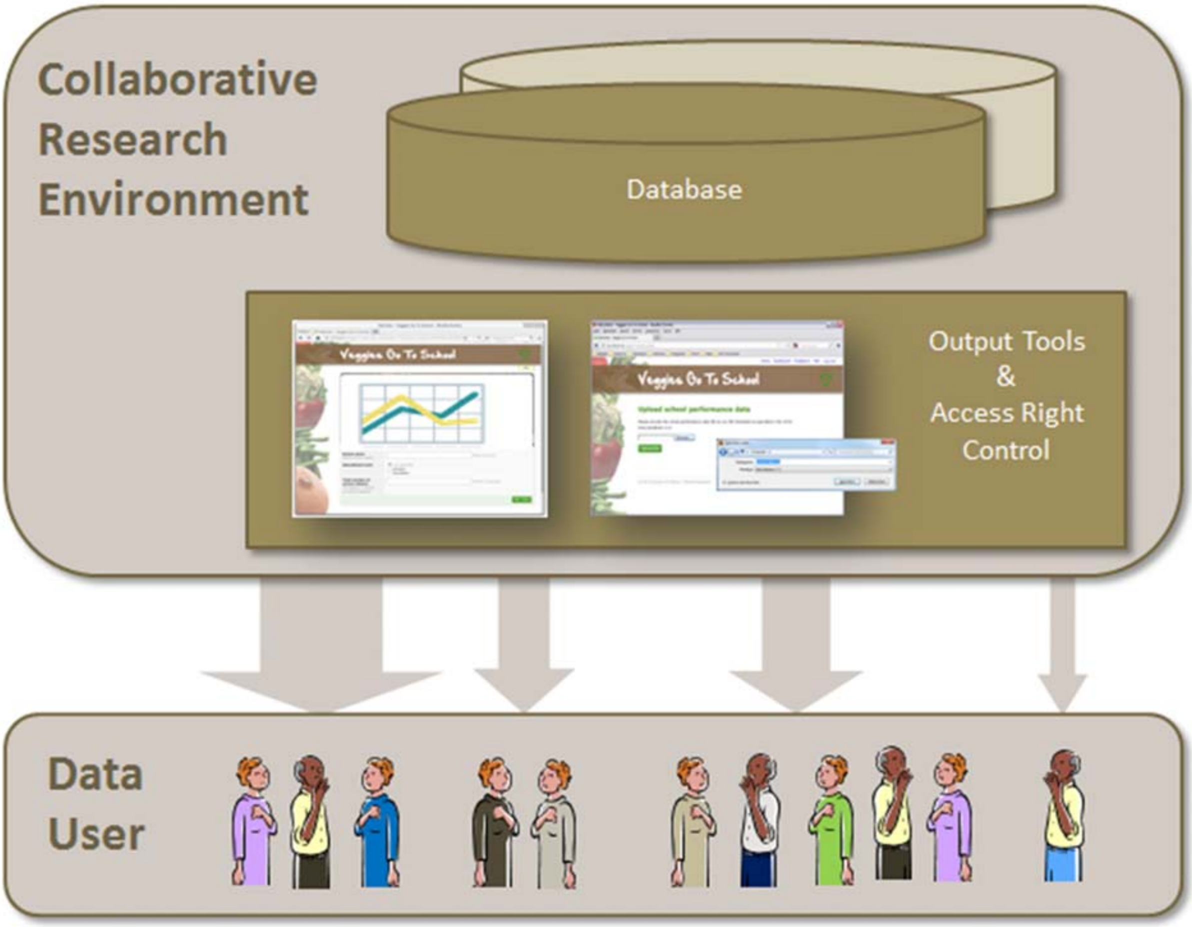

Figure 6 Output data workflow. Note that different users and user groups have different access to data.

8.3 Data generation of the project for research and evaluation

Within the VGtS project we have to deal with two groups of data: already existing data and data collected / generated by the country teams or scientists of the VGtS project during project lifetime.

For existing data (e.g. school statistics and the like), data availability and data accessibility has to be ensured by each country data manager. The data from different countries / agencies need to be transformed into a common structure for inclusion in the CRE.

For data generated by the project (e.g. data on a specific school garden) the CRE provides means to directly create the data online using the CRE and/or upload data from files. The advantage of data generated by the project is that it will already be created according to a common structure.

The following tables 1-3 provide a tentative draft list of required data. Core data sets are necessary to describe schools, school gardens and school children.

Some of the data is static and needs to be collected and entered into the CRE only once (e.g. school location). Other data might change during the project and has to be updated on a regular basis. Some of the attributes are straightforward, e.g. school name and location. Some of the attributes need to be further elaborated.

These lists are by no means exhaustive and must be extended and adjusted during the ToT workshop according to the specific needs of the countries, to the scientific requirements and to allow for an effective project monitoring and project evaluation.

Table 4 Tentative list of data describing schools

Mandatory	Variable Name
M	School name
M	Geographic location
M	School district location
M	Location type (urban, peri-urban, rural area)
M	Educational Level (primary, secondary)
M	School type (public, private)
M	Education type (boys school, girls school, mixed
M	Approximate total number of school children
M	Approximate total number of teachers
M	Contact details school
O	Date of establishment
M	Responsible VGtS contact at school
M	Internet accessibility for school administration?
M	Internet accessibility for school children?
M	Language(s) at school lessons
M	Language(s) between school children
M	Language preference for data entry (en/fr)
M	Language preference for public access website

M	Language preference for project data and analysis
M	Status within VGtS project (pilot with school garden, pilot w/o school garden, …)
M	Status of sanitation and hygiene (SDC's Blue School Programme, …)
M	Overall school performance
M	Overall school children nutrition status
M	Overall school children health status
O	General data on the surrounding communities location, land use, income sources, infrastructure, sanitation, food sources and diets, other geographic data)
	…

Data collection on schools should be in the responsibility of the country data manager. This person has to make sure that the required data is available, reformatted to the specifications and uploaded through the web interface of the CRE.

Table 5 Tentative list of data describing school gardens

Mandatory	Variable Name
M	Responsible person
M	Number of related school children
M	Age range of related school children
M	Status of garden (planned, implemented, abandoned)
M	Size of garden
M	Structure of garden
M	Access to water
M	Environmental conditions
O	Soil type
O	Photos
O	Videos
M	Crops grown
O	Harvest cycle(s)
	…

Data on school gardens could be collected, uploaded and updated through the web interface of the CRE by the school garden responsible person from each school or a person assigned by the country data manager to do so. It is in the responsibility of the country data manager that project schools provide the required data.

Table 6 Tentative list of data on individual school children

Mandatory	Variable Name
M	Name
M	Sex
M	Age
M	Distance from home to school
M	Size of family / household
M	Economic status of family / income
M	School performance
M	Nutrition status
M	Health status
M	Is school garden “farmer”?
M	Is school garden crop “consumer”
	…

Data on individual school children might be collected, uploaded and updated through the web interface of the CRE by the school responsible person from each school or a person assigned by the country data manager to do so. It is in the responsibility of the country data manager that project schools provide the required data. Depending on the use case data on individuals might also be produced by research teams involved in project. These groups should also have the possibility to insert or upload respective data into the CRE.

8.4 What data will be generated for outreach and for communication between the VGtS schools and between school children participating in VGtS?

This data is primarily targeted at promotion of the project and stimulating schools / school children to participate in the school garden program and pertains to the dissemination domain. Consequently scientific analysis is not the focus of this data.

The CRE will provide a specific user interface for this application domain. The interface will be more of a social media type that supports participation and involvement of school teachers and school children.

Individuals should readily be able to participate in data production and should have a large share in deciding what data / information they are willing to share with others.

Again there will be information on the three levels school, school gardens, and school children. A tentative list of possible content is given in Tabs. 4 through 6.

Table 7 Tentative list of content useful for communicating about schools

Mandatory	Variable Name
	Publicly accessible data from Table 1
	Stories
	Photos
	Videos
	Audios
	…

Such content on schools might be created by school masters/mistresses, teachers, and even school children themselves.

Table 8 Tentative list of content useful for communicating about school gardens

Mandatory	Variable Name
	Publicly accessible data from Table 2
	Stories
	Photos
	Videos
	Audios
	…

Content on school gardens could be presented in a range of different formats. A school garden diary might be written including photos and videos. Such content on school gardens might be created and posted on the web platform by school masters/mistresses, teachers, and even school children.

Table 9 Tentative list of content useful for communication between schoolchildren

Mandatory	Variable Name
	Name
	Photo
	Map of way to school
	Language(s) I speak
	About my family
	My school garden activities (garden

diary)
Favourite school garden plant
Stories
Audios
Videos
…

Content from individual school children could be posted through a suitable web interface by school children themselves or by a teacher. The school garden responsible person from each school might create and manage accounts for his/her school children.

8.5 Data Access Policy

To ensure efficient data flow within the project a data policy is required. The data policy needs to clarify the following topics:

- Who is the responsible person for each country for data provision to the project (i.e. who is the country data manager)?
- During the project lifetime, what data will be available to which project partners?
- For which data sets must we consider privacy issues with data on individuals?
- Which cultural or gender aspects do we have to consider when we collect and/or publish data?
- For which data sets must we consider legal constraints in using or publishing the data?
- Are there data sets with a period of retention on data access?

8.6 Requirements for successful data management

On the institutional level

- Identify and name responsible persons for data collection and upload
- Assign sufficient resources for data collection, formatting and quality assurance
- Instruct the persons assigned to data collection why it is important to prepare the data carefully

On the technical level

- Assign a technically able person to the preparation of existing data sets for inclusion in the CRE
- Provide metadata for the collected data
- Adhere to the data specifications as given by the project

Annex 1: Terms of Reference for the local project teams

Country Manager, Country Teams and Senior Government Officer involved with the Vegetables Go to School Project (Bhutan, Nepal, Burkina Faso, and Tanzania)

Country Manager

The Country Manager will be a full-time project staff and will be in charge of the project implementation in the country. The Country Team should nominate a person for this position. The AVRDC Director of Human Resources together with the Project Manager will assess his/ her qualifications and can decide to accept or reject the nomination.

The following qualifications are important for the Country Manager:

- He/she should have close connections to the lead implementing agency (usually the Ministry of Education) in order to be able to effectively implement the project. We encourage the deputation of an existing (or recently retired) staff member to the project.
- He/she should have excellent communication skills and able to motivate people for the project. Previous experience in managing training programs would be an advantage.
- He/she should be able to communicate in English.

The Country Manager will report directly to the Project Manager. The Country Manager is a full-time appointed position with a remuneration paid by AVRDC through the relevant ministry, an NGO or AVRDC regional office (if present). We expect the Country Manager to participate in the Training-of-Trainers Workshop and Policy Workshop from 19 August to 13 September in Taiwan. He/She would therefore be a member of the Country Team.

Country Teams

One government officer each from the ministries of Education, Agriculture and Health constitute a Country Team. The Country Manager is also part of this team. Team members need to be senior enough to implement the school vegetable garden project in their country. Previous experience with school garden programs would be an advantage. They must have a working knowledge of English. To ensure gender balance, the Country Team must include at least one man and one woman.

Country Team members, except for the Country Manager, are part-time members of an implementation team, voluntary or assigned by the ministry, and are not paid for their services. The key incentives for the Country Team members are participation in the workshops at AVRDC, to derive satisfaction out of an interesting creative work, and international exposure.

The Country Team will have the following tasks:

1. Actively participate in the Training-of-Trainers Workshop and Policy Workshop from 19 August to 13 September in Taiwan.

2. During this workshop the Country Team will jointly write an eight-year **Vegetables Go to School Action Plan** for implementing school vegetable gardens in their country, which should cover the following topics:
    - Current status of school gardens in the country
    - Objectives and expected outcomes of school vegetable gardens
    - An implementation plan, including:
        - A **school selection plan** defining the criteria for targeting schools over three phases of the project.
        - A **garden design plan** that includes the selection of suitable crops, irrigation methods, and methods of integrated crop and pest management.
        - A **vegetable seed supply plan** specifying how schools will regenerate vegetable seed supplied by AVRDC.
        - A **promotion plan** to make school vegetable garden activities interesting, attractive and fun for school girls and boys.
        - A **nutritional impact plan** to ensure that the school vegetable garden contributes to nutritional outcomes and has positive synergies with other health and environmental promotion activities.
    - Draft curricula for (a) the training of school teachers and (b) the training of school girls and boys. These could be based on existing training materials and the country teams are expected to bring these to the workshop.
    - A strategy for evaluating the impact of school vegetable gardens by systematically collecting, analyzing and sharing data and using the results to continuously improve the performance of school vegetable gardens.
    - A scaling-out strategy for the second phase of the project (2016-2018).
    - A budget and time plan for the first phase of the project (2013-2015) including milestones to be achieved.
    - A strategy for attracting additional resources for establishing and maintaining school vegetable gardens from the government, private sector or donors.
3. After returning from the workshop, the Country Team will support the Country Manager in implementing the Vegetables Go to School Action Plan. The team is expected to meet regularly to discuss progress and address constraints.

Senior Government Officer

To ensure enough support for the implementation of the Vegetables Go to School Action Plan, we invite one Senior Government Officer to Taiwan to attend the Policy Workshop on school vegetable gardens. This person could for instance be a *Principal, Permanent or Deputy Secretary* or *Director* who can support and catalyst changes in policies to favor the project outcomes. The Senior Government Officer will be welcomed by the Director-General of AVRDC, the senior management of AVRDC and the AVRDC Regional Directors. The person will also be able to meet their counterparts from other countries as well as government officials from Taiwan. The Policy Workshop will highlight the potential of school vegetable gardens by presenting success stories from the Philippines, Thailand, Taiwan and the United States. After this, the Senior Government Officer is expected to work closely with his/her Country Team to adjust the Action Plan and develop a strategy for implementation, scaling-out and attracting additional resources.

Annex 2: Relevant literature

A. School gardens and related literature

1. AVRDC. 1990. Vegetable Production Training Manual. Shanhua, Taiwan: AVRDC-The World Vegetable Center, Available online at: http://203.64.245.61/fulltext_pdf/EB/1900-2000/eb0130.pdf
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4. AVRDC. 2005. Saving your own vegetable seeds. A guide for farmers. Shanhua, Taiwan: AVRDC-The World Vegetable Center, Available online at: http://203.64.245.61/web_docs/manuals/save-your-own-veg-seed.pdf (also available in Bahasa Indonesia)
5. Centers for Disease Control and Prevention. Strategies to Prevent Obesity and Other Chronic Diseases: The CDC Guide to Strategies to Increase the Consumption of Fruits and Vegetables. Atlanta: U.S. Department of Health and Human Services; 2011. Available online at: http://www.cdc.gov/obesity
6. FAO. 2005. Setting up and running a school garden. A manual for teachers, parents and communities. Rome: Food and Agriculture Organization of the United Nations, 198 pp. Available online at: http://www.fao.org/docrep/009/a0218e/a0218e00.HTM
7. FAO. 2009. Setting up and running a school garden. Teaching toolkit. Rome: Food and Agriculture Organization of the United Nations, 193 pp. Available online at: http://www.fao.org/docrep/012/i1118e/i1118e00.htm
8. WHO. 2013. State of School Feeding Worldwide 2013. Rome: World Food Programme, 124 pp. Available online at: http://home.wfp.org/stellent/groups/public/documents/communications/wfp257482.pdf

B. Interesting web links

9. **KidsGardening** – Helping young minds grow. National Gardening Association (NGA) (United States) http://www.kidsgardening.org
10. **Girls Education Collaborative** – the whole girl. the whole world. US-based charity (Buffalo, NY). Working in northern Tanzania (Kitenga village project). http://girlsedcollaborative.org/
11. California Department of Education – School garden program. http://www.cde.ca.gov/ls/nu/he/gardenoverview.asp
12. South Carolina Department of Agriculture. South Carolina School Gardens Program. http://agriculture.sc.gov/schoolgardens
13. **Team Nutrition**, United States Department of Agriculture

    http://teamnutrition.usda.gov/Resources/gardendetective.html

    http://teamnutrition.usda.gov/Resources/dig_in.html

    http://teamnutrition.usda.gov/library.html
14. **National Organization for Agriculture in the Classroom**

    http://www.agclassroom.org/
15. **The Edible Schoolyard**

    http://edibleschoolyard.org/

16. **Nutrition for Kids**

    http://nutritionforkids.com/

17. **LifeLab**

    http://www.lifelab.org/

18. **National Farm to School Network**

    http://www.farmtoschool.org/

19. **Sustainable Agriculture Research and Education**

    http://www.sare.org/Learning-Center/Courses-and-Curricula/Youth-Education-Curriculum-Guides

20. **Teaching the Food System**, John Hopkins School of Public Health

    http://www.jhsph.edu/research/centers-and-institutes/teaching-the-food-system/curriculum/

C. Scientific literature on the impact of school gardens

Electronic copies of all these articles are available

21. Aguilar O.M., Waliczek T.M. and Zajicek J.M. 2008. Growing Environmental Stewards: The Overall Effect of a School Gardening Program on Environmental Attitudes and Environmental Locus of Control of Different Demographic Groups of Elementary School Children. HortTechnology 18: 243-249.
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28. Goldman, R., Radnitz, C., McGrath, R. 2012. The role of family variables in fruit and vegetable consumption in preschool children. Journal of Public Health Research 1(2), Available at: http://www.jphres.org/index.php/jphres/article/view/jphr.2012.e22/47.
29. Graham, H. et al. (2005) Use of School Gardens in Academic Instruction. Journal of Nutrition Education and Behavior. 37: 3: 147-151.
30. Heim S., Stang J. and Ireland M. 2009. A Garden Pilot Project Enhances Fruit and Vegetable Consumption among Children. Journal of the American Dietetic Association 109: 1220-1226.
31. Jaenke R.L., Collins C.E., Morgan P.J., Lubans D.R., Saunders K.L. and Warren J.M. 2011. The Impact of a School Garden and Cooking Program on Boys' and Girls' Fruit and Vegetable Preferences, Taste Rating, and Intake. Health Education & Behavior 39: 131-141.
32. Kommu, V. 2010. Students Grow Their Own Vegetables in School Yards, Field Actions Science Reports [Online], Special Issue 1 | 2010. http://factsreports.revues.org/434

33. Krolner R., Rasmussen M., Brug J., Klepp K.-I., Wind M. and Due P. 2011. Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part II: qualitative studies. International Journal of Behavioral Nutrition and Physical Activity 8: 112.
34. Langellotto G.A. and Gupta A. 2012. Gardening Increases Vegetable Consumption in School-aged Children: A Meta-analytical Synthesis. HortTechnology 22: 430-445.
35. Libman K. 2007. Growing Youth Growing Food: How Vegetable Gardening Influences Young People's Food Consciousness and Eating Habits. Applied Environmental Education & Communication 6: 87-95.
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Annex 3: Tips for successful school vegetable gardens

Please add more tips everyone!!

- **Children are learners, not labor.** Make sure that the school girls and boys enjoy the garden; otherwise they won't learn from it. If the garden is large then appoint a garden manager to do the regular garden work.
- **Seeds and money.** The sustainability of the garden will to a large extent depend on the supply of seeds and a small but regular supply of money to maintain the garden. It is best if the schools do not depend on outside help for these. If the supply of seeds and money might be a problem, then start the garden small and expand later.
- **Fencing** of the school gardens is often essential.
- **Support of the school teachers, principal, parents and children, and the community** will be essential for the school garden to thrive. Involve them as early as possible and allow them to participate in as many decisions as possible.
- **Provide child-size tools.** Handles of shovels, rakes, and hoes may need to be shortened for use by smaller hands.
- **Stay cool.** If your garden is in the tropics, schedule garden work early in the morning or at times when there is more shade. Drinking water should be available for students working in the garden.
- **Set more frequent, but shorter work sessions**. Garden work is more enjoyable in small doses!
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