Emerging strategy and opportunities in horticulture (ANNEX)

March 25, 2010
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• Horticulture market dynamics

• The income case for horticulture

• The nutrition case for horticulture

• Funding landscape

• Field visit learnings

• List of people interviewed
Fruits and vegetables comprise 16% of SSA agricultural crop consumption, the 3rd largest category after roots & tubers and cereals.

### Total agricultural consumption in SSA (2003, in M tonnes)

<table>
<thead>
<tr>
<th>Category</th>
<th>Excluding</th>
<th>Cereals - Excluding Beer</th>
<th>Fruits - Excluding Wine</th>
<th>Vegetables</th>
<th>Legumes</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roots &amp; tubers</td>
<td>239</td>
<td>179</td>
<td>63</td>
<td>41</td>
<td>19</td>
<td>90</td>
</tr>
<tr>
<td>Roots, Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roots &amp; Tuber Dry Equiv</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet Potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cassava</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Starchy Roots</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: “Potential horticulture” includes some roots/tubers (e.g. carrots) and some legumes (e.g. “cowpeas”); Other includes sugars, legumes, oils, coffee, cocoa, tea, spices; Excludes livestock and fish; Excludes Morocco, Algeria, Tunisia, Libya, Egypt and South Africa. 

Source: FAOSTAT

Interviews suggest leaves of roots and tubers (e.g. cassava, sweet potatoes) are consumed widely in SSA.

FAO data groups many vegetables together (e.g. exotic and indigenous leafy greens).
The majority of households in SSA consume at least some fruits and vegetables

Percentage of HHs consuming fruits or vegetables

Source: “Patterns and determinants of fruit and vegetable consumption in sub-Saharan Africa” (Ruel et al, 2005)
Domestic markets are a primary focus because 95% of horticulture production remains in country and 97% of consumption is local.

Vast majority of fruits and vegetables produced in Africa remain in country

<table>
<thead>
<tr>
<th>Total African Production (2005) (millions of tonnes)</th>
<th>Export out of region</th>
<th>Export in region</th>
<th>Remain in country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td>0%</td>
<td>8%</td>
<td>92%</td>
</tr>
<tr>
<td>Vegetables</td>
<td>2%</td>
<td>0%</td>
<td>98%</td>
</tr>
</tbody>
</table>

Percentage remaining in country likely higher due to "hidden" horticulture (e.g., indigenous vegetables).

Only 3% of total consumption is imported

<table>
<thead>
<tr>
<th>Consumption and imports</th>
<th>Imports</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total consumption</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>Total imports</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

FOR VALIDATION

Note: Discrepancies between consumption and production in FAO, further validation required; Export production breakdown uses 2005 production figures with 2003 export percentages; Import figure likely higher but not reported; Assumes that fruit import rates are the same as vegetable import rates.

Source: FAO; Dalberg analysis.
In domestic East African horticulture, there are ~6 crops that can be classified as “mass market”

<table>
<thead>
<tr>
<th>Domestic “mass” market</th>
<th>Vegetables</th>
<th>% of volume traded (Kenya)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabbage</td>
<td></td>
<td>8.4%</td>
</tr>
<tr>
<td>Kales (a.k.a. “sukuma wiki” or “rape”)</td>
<td></td>
<td>8.2%</td>
</tr>
<tr>
<td>Tomatoes</td>
<td></td>
<td>6.8%</td>
</tr>
<tr>
<td>Exotic and indigenous leafy greens*</td>
<td>1-2%</td>
<td></td>
</tr>
<tr>
<td>Onions</td>
<td></td>
<td>1.7%</td>
</tr>
<tr>
<td>Bananas**</td>
<td></td>
<td>23.0%</td>
</tr>
<tr>
<td>Mangoes</td>
<td></td>
<td>3.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Domestic “niche” market</th>
<th>Vegetables</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrots</td>
<td></td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Sweet and hot peppers</td>
<td></td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Butternut squash</td>
<td></td>
<td>&lt;1%</td>
</tr>
<tr>
<td>African eggplant</td>
<td></td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Domestic processing</th>
<th>Fruits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Passion</td>
<td></td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Watermelon</td>
<td></td>
<td>&lt;1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fruits</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pineapples†</td>
<td>9.1%</td>
</tr>
<tr>
<td>Mango, passion, guava, apple, citrus</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: Crop list synthesizes across expert interviews with on-the-ground stakeholders, *Includes amaranth, black nightshade, spiderplant, cowpea leaves, cassava leaves and spinach; **Includes both cooking and sweet varieties, †Bulk of production comes from Delmonte farm and Kakuzi Ltd

Source: 1) From TNS Kenya (sourced from Ministry of Agriculture, Customs, and KEPHIS), data indicates % of total fruit and vegetable volume captured in database, total includes Irish Potatoes (25% of volume traded)
Cost per 100g serving of mass market horticulture commodities is comparable to staple grains

Early morning wholesale prices per 100g (Kenyan Shillings)

- Wheat: 0.30
- Dry maize: 0.24
- Green maize: 0.31
- Cassava: 0.10
- Cabbage: 0.16
- Kale: 0.14
- Tomato: 0.50
- Onions: 0.35
- Sweet banana: 0.39
- Cooking banana: 0.18
- Mango (local): 0.08
- Mangoes Ngowe: 0.22

Staples (current portfolio focus)

“Mass market” horticulture

At current exchange rate, 0.50 KES is ~ 2/3 US cent

Note: Based on wholesale price quoted at Nairobi market on March 1, 2010; prices for rice and indigenous vegetables not available.

Source: Kenya Ministry of Agriculture, Market Research and Information
Historical and projected consumption growth imply sufficient demand to absorb production increases

**Significant historical demand growth for horticulture in Africa...**

Historical consumption CAGR (93-03)

- **Asia**: 6.4%
- **Africa**: 4.2%
- **Latin America**: 3.7%
- **Oceania**: 3.6%
- **US & Canada**: 2.7%
- **Europe**: 2.2%

![Graph showing historical consumption CAGR for different regions.]

**...are coupled with growth forecasts above rest of world**

Projected annual consumption growth (2007-2012)

- **Central Asia**: 4.4%
- **Africa**: 4.2%
- **Latin America**: 2.7%
- **US & Can**: 1.9%
- **W. Europe**: 1.3%

![Graph showing projected annual consumption growth for different regions.]

Source: FAO (Asia includes Middle East; Latin America includes Caribbean)

Source: Euromonitor
Local income elasticities confirm that rising incomes will be met with growing demand for fruits and vegetables.

**Income elasticities for fruits and vegetables**

<table>
<thead>
<tr>
<th>Country</th>
<th>Fruits</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burundi</td>
<td>1.1</td>
<td>0.6</td>
</tr>
<tr>
<td>Kenya</td>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Rwanda</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>Tanzania</td>
<td>0.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Uganda</td>
<td>0.5</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Source: 1) “Patterns and determinants of fruit and vegetable consumption in Sub-Saharan Africa” (Ruel et al, 2005); 2) United Nations Statistics Division (using World Bank historical GDP deflators)

**Compound annual growth rate in per capita gross national income (real currency)**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Burundi</td>
<td>2.4</td>
<td>-4.1</td>
</tr>
<tr>
<td>Kenya</td>
<td>3.5</td>
<td>7.6</td>
</tr>
<tr>
<td>Rwanda</td>
<td>4.7</td>
<td>16.4</td>
</tr>
<tr>
<td>Tanzania</td>
<td>2.8</td>
<td>-0.4</td>
</tr>
<tr>
<td>Uganda</td>
<td>3.0</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Note: Income elasticity of 0.60 for fruit indicates that for 10% increase in income there will be a 6% increase in percentage of total budget allocated to fruit.
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- The income case for horticulture
- The nutrition case for horticulture
- Funding landscape
- Field visit learnings
- List of people interviewed
Production of horticultural crops in East Africa is widespread, offering the potential to reach ~10 million smallholder farmers.

Estimated # of smallholder farmers growing horticulture in East Africa, Kenya extrapolation*

- **All SHFs¹**: ~9-13M
- **No horticulture production²**: ~1-1.5M
- **Horticulture production for on-farm consumption only²**: ~2.5-3.5M
- **Horticulture production for domestic sale²**: ~5-7.5M
- **Horticulture production for export only³**: <0.5M

*Horticulture market in Kenya is relatively advanced; ranges reflect likely overstatement when applied to region

Note: # of smallholder farmers in EA relative to SSA assumed to be proportional to population differences between EA and SSA

Source: 1) Key note address by Lennart Bage (IFAD President) to African Green Revolution Conference, August 2008, 2) Tegemeo Institute, unpublished 2007 survey data (nationally representative survey, Kenya), 3) Interview with Steve Mbithi, CEO of FPEAK
Horticulture offers 5-8x income increases for SHFs over staple crops, as well as indirect employment and commercialization benefits

Field interviews and intervention successes confirm SHF income potential from horticulture

“Value for horticulture is roughly 5-8 times that of any staple crop per unit of land”

--Steve Mbithi, CEO of Fresh Produce Exporters Association of Kenya

USAID’s Kenya Horticulture Development Program (KHDP) demonstrated ~7x income increases:

- $12M, 5-year project addressed multiple constraints across multiple crops within designated geographical areas, reaching ~1,200 farmer groups
- Local market sales accounted for more than 70% of grower income in 4 of the 5 areas, with the exception demonstrating the lowest income growth

Additional indirect income and employment is created through production, value-add, and commercialization

“[Horticulture provides] employment and wages to laborers…Often, horticultural production requires twice as much, sometimes up to four times as much labor than the production of cereal crops.”

% of farms using paid labor

<table>
<thead>
<tr>
<th></th>
<th>Horticultural farmers</th>
<th>Non-horticultural farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>60%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Horticulture also provides indirect income opportunities from value-add and commercialization:

- Employment opportunities in post-harvest and processing create additional jobs, often for women
- Relative to staples, horticulture is more likely to be sold rather than consumed on farm, creating cash flow, trade, and increased demand for local businesses

Average production costs tend to be higher for horticultural crops than either cash or staple crops.

Total costs of production (Uganda example, USD per ha)

Note: Averages based on recommended practices; 1 USD = 2016 UGX; okra, papaya, onion and tomato taken from Robinah et al; all other crops from Aliguma.

Source: “Small farmer participation in export production: The case of Uganda” (L Aliguma, July 2003); “Pro-poor Horticulture in East Africa and South East Asia: The Horticultural Sector in Uganda” (Robinah Sonko et al, January 2005)
However, horticultural commodities typically offer higher returns than staple crops.

Gross margin for selected crops under treadle pump irrigation on one hectare of land (Malawi, in MK)

Note: “High level management” not available for tobacco
Source: “Vegetable Research and Development in Malawi: Review and Planning Workshop Proceedings” (AVRDC, Sept 03)
Additional data from Kickstart corroborates finding that horticulture has higher production costs and higher returns.

Total costs of production per acre (Kenya example, thousand KES per acre per year)

Note: Further analysis of underlying data set required (income data likely overestimated)

Source: Kickstart 18-Month Follow-Up Survey (based on treadle pump irrigation)
Horticulture production as a means of generating income is important to SHFs regardless of proximity to urban centers or income quartile.

Percentage of households selling FFV by region (Kenya 2007)

<table>
<thead>
<tr>
<th>Region</th>
<th>Percentage Selling FFV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Lowlands</td>
<td>79</td>
</tr>
<tr>
<td>Eastern Lowlands</td>
<td>73</td>
</tr>
<tr>
<td>Western Lowlands</td>
<td>74</td>
</tr>
<tr>
<td>Western Transitional</td>
<td>87</td>
</tr>
<tr>
<td>High Potential Maize Zone</td>
<td>73</td>
</tr>
<tr>
<td>Western Highlands</td>
<td>92</td>
</tr>
<tr>
<td>Central Highlands</td>
<td>91</td>
</tr>
</tbody>
</table>

Note: Based on rural household population survey (n = 1309); Central highlands, Western highlands, and Coastal Lowlands serve Nairobi, Kisumu and Mombasa, respectively; FFV = fresh fruits and vegetables; *Income quartile per adult equivalent; Urban areas are estimated to account for over 80% of growth in demand for FFV over next 25 years.

Source: “Assessment of Kenya’s Domestic Horticultural Production and Marketing Systems and Lessons for the future” (Tschirley and Ayieko, Tegemeo Institute, Sept 2008)
Moreover, horticulture is a particularly important source of income to the most marginal of smallholders.

**Household share of income from FFV production by income quartile** (Kenya 2007)

- Top quartile: 7%
- Second quartile: 12%
- Third quartile: 12%
- Bottom quartile: 18%

**Household share of land allocated to FFV production by income quartile** (Kenya 2007)

- Top quartile: 29%
- Second quartile: 36%
- Third quartile: 39%
- Bottom quartile: 43%

Note: Based on rural household population survey (n = 1309); FFV = fresh fruits and vegetables; *Income quartile per adult equivalent

Source: “Assessment of Kenya’s Domestic Horticultural Production and Marketing Systems and Lessons for the future” (Tschirley and Ayieko, Tegemeo Institute, Sept 2008)
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When targeting nutritional outcomes, agricultural development is most important for creating household availability of necessary foods.

**Sources of food**

- Own food production
- Food Purchases
- Gifts of food
- Collection of wild foods

**Agriculture development**

Targets increased availability, via food production and purchases (by increasing incomes)

**Global health**

Also attentive to how household availability is translated into individual nutritional status (especially <2 years)

- Food distribution within household
- Child feeding practices
- Appetite suppression due to disease
- Dietary quality
- Disease
- Food preparation

Source: Adapted from “Maternal and Child Undernutrition” Series (The Lancet, 2008)
Horticulture is important from a nutrition perspective, as consumption is far below WHO guidelines

Source: FAOSTAT, 2004; WHO
## Macronutrients

**Function:** Provide structural material and energy

**Types:**
- Carbohydrates
- Fats
- Protein
- Fiber
- Water

Recommended ratio of energy sources:

<table>
<thead>
<tr>
<th>Carbohydrates</th>
<th>Fat</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>72%</td>
<td>17%</td>
<td>11%</td>
</tr>
</tbody>
</table>

Total Calories

### BMGF Priorities: Energy intake for children -9 to 24 months and pregnant/lactating women

| Mean requirement: 2100 Calories* |

## Micronutrients

**Function:** Act as coenzymes and cofactors in numerous metabolic processes
- Many are directly or indirectly involved in gene expression

**Types (not exhaustive):**

### Minerals
- Calcium
- Magnesium
- Iodine
- Iron
- Selenium
- Zinc

### Vitamins
- Vitamin A
- Vitamin C
- Vitamin D
- Vitamin E
- Vitamin K
- B Vitamins

### BMGF Priorities: Vitamin A, Iron, Zinc, Folic Acid, Iodine

Note: *Requirements vary significantly by age, gender and health status; mean is based on weighted average across subgroups; †List of micronutrients is not exhaustive (focus is on most significant)

Fruits/vegetables can be good sources of simple carbs, protein, and fiber but are generally not the most effective source of macronutrients.

<table>
<thead>
<tr>
<th>Macronutrient</th>
<th>Subcategory</th>
<th>Key Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>Complex</td>
<td>Legumes, <strong>starchy vegetables</strong> (e.g., roots and tubers), whole grain bread</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and cereals</td>
</tr>
<tr>
<td></td>
<td>Simple</td>
<td><strong>Fruits</strong>, milk and milk products, <strong>vegetables</strong></td>
</tr>
<tr>
<td>Fats</td>
<td>Saturated</td>
<td>Animal products (butter, whole milk, cream, fatty meat), some vegetable oils</td>
</tr>
<tr>
<td></td>
<td>Unsaturated</td>
<td>Fish, corn, sunflower, safflower</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Olive, canola, soybean oils</td>
</tr>
<tr>
<td></td>
<td>Trans Fatty Acids</td>
<td>Margarines, fried and processed food</td>
</tr>
<tr>
<td></td>
<td>Hydrogenated, partially hydrogenated</td>
<td>Hardened oils (butters, margarines)</td>
</tr>
<tr>
<td>Proteins</td>
<td>Complete</td>
<td><strong>Meat</strong>, fish, poultry, eggs, milk, milk products, soy</td>
</tr>
<tr>
<td></td>
<td>Incomplete</td>
<td>Beans, peas, nuts, seeds, grain</td>
</tr>
<tr>
<td>Fiber</td>
<td>Soluble</td>
<td><strong>Oat bran</strong>, barley, nuts, seeds, beans, lentils, peas, **some fruits and</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>vegetables</strong></td>
</tr>
<tr>
<td></td>
<td>Insoluble</td>
<td><strong>Wheat bran</strong>, <strong>vegetables</strong>, and whole grains</td>
</tr>
<tr>
<td>Water</td>
<td>NA</td>
<td><strong>Drinking water</strong>, soup, milk, juices</td>
</tr>
</tbody>
</table>

Source: University of Maryland Medical Center
<table>
<thead>
<tr>
<th>Micronutrient</th>
<th>Role in development/human health</th>
</tr>
</thead>
</table>
| Vitamin A    | • Vitamin A deficiency is the **leading cause of preventable blindness** in children<sup>1</sup>  
• Insufficient Vitamin A **increases the risk of disease and death** from severe infections<sup>1</sup> |
| Iron         | • Iron deficiency (anemia) is the **most common and widespread nutritional disorder** in the world<sup>1</sup>  
• Major health consequences of iron deficiency include **poor pregnancy outcome, impaired physical and cognitive development, increased risk of morbidity** in children and **reduced work productivity** in adults<sup>1</sup> |
| Zinc         | • Zinc deficiency in children results in **increased risk of diarrhea, pneumonia, and malaria**<sup>2</sup>  
• **Growth stunting** is also a common clinical manifestation of zinc deficiency<sup>2</sup> |
| Folic acid   | • Critical for the **production and maintenance of new cells**<sup>3</sup>  
• **Reduces the risk of serious birth defects** that result from improper neural tube development<sup>3</sup> |
| Iodine       | • Iodine deficiency is a main cause of **impaired cognitive development** in children<sup>1</sup>  
• Iodine deficiency during pregnancy **can lead to severe congenital abnormalities**<sup>1</sup> |
| Calcium*     | • Most abundant mineral in the body; **supports bone and teeth structure**<sup>3</sup>  
• Also required for muscle contraction, blood vessel expansion and contraction, secretion of hormones and enzymes, and nerve signal transmission<sup>3</sup> |
| Vitamin D*   | • Plays a role in absorption and retention of calcium and phosphorus<sup>4</sup>  
• Help to **prohibit cancer growth and control infections**<sup>4</sup> |

*May be included as part of 2010 Nutrition Strategy Refresh
Source: 1) World Health Organization (“Micronutrients”); 2) “Maternal and Child Undernutrition” (The Lancet); 3) NIH Office of Dietary Supplements; 4) Harvard School of Public Health
Insufficiencies for these micronutrients are pronounced in sub-Saharan Africa

**Vitamin A¹**

**Iron²**

**Zinc³**

**Iodine⁴**

Note: For some nutrients (e.g., fat-soluble vitamins such as Vitamin A) there can be risk of overconsumption; Risk of excess iodine in some SSA countries likely have high iodine content in soils; map of folic acid deficiency not available in Lancet/WHO

There are a number of fruits and vegetables that are attractive sources of Vitamin A.

Key Findings

“Orange fleshy” fruits and vegetables are particularly high in Vitamin A content --mangoes

--orange roots and tubers such as sweet potato and carrots also attractive

“Green leafy” vegetables also a good source

--kale, swiss chard

--leaves of staples such as cassava

--IVs such as amaranth and nightshade

[Note: specific production data not available from FAO]
Legumes, nuts and indigenous vegetables are the best sources of aggregate iron content; bioavailability may be limited relative to meat.

Note: Includes commodities from FAOSTAT with >5K tonnes East Africa production in 2007 for which there is nutritional information in World Food 2.0 Kenya/Senegal databases; Excludes commodities for which iron content is less than 0.1g/100g serving; Beef liver is very high in iron (7mg/100g) but excluded from chart; Amaranth and nightshade from AVRDC (Tanzania example, average across regions); Commodity classifications taken from FAO; Nutritional information based on 100g of product as consumed (Raw-Edible Portion); Size of bubble indicates total East African production (2007)

Source: Production data taken from FAOSTAT; Nutrition content taken from World Food Dietary Assessment System Version 2.0 (Kenya and Senegal Databases)
Zinc is best obtained through meats and legumes; fruits and vegetables are not priority sources.

**Key Findings**

- **Zinc typically found in foods that are high in protein** (meats and legumes).
- **Staple crops are more attractive sources of zinc than fruits and vegetables** (commodities with less than 0.1mg per 100g serving excluded from chart, including many horticultural commodities).

Note: Includes commodities from FAOSTAT with >5K tonnes East Africa production in 2007 for which there is nutritional information in World Food 2.0 Kenya/Senegal databases; Excludes commodities for which zinc content is less than 0.1g/100g serving; Amaranth and nightshade from AVRDC (Tanzania example, average across regions); Commodity classifications taken from FAO; Nutritional information based on 100g of product as consumed (Raw-Edible Portion); Size of bubble indicates total East African production (2007).

Source: Production data taken from FAOSTAT; Nutrition content taken from World Food Dietary Assessment System Version 2.0 (Kenya and Senegal Databases).
Legumes & nuts and the leaves of staple crops appear to be the most attractive sources of folate.

Data on folate content of IVs not available, but high content in leaves of staple crops suggests IVs may also be an attractive source.

Key Findings

Legumes and nuts are the major source of folate.

Green leaves are also high in folate.

Note: specific production data not available from FAO.
Beyond dietary diversity, there are three major approaches to increasing the availability of priority micronutrients:

<table>
<thead>
<tr>
<th>Description</th>
<th>Dietary diversity</th>
<th>Supplementation</th>
<th>Fortification</th>
<th>Biofortification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase consumption of fruits, vegetables, meats and dairy goods that are naturally high in target nutrients</td>
<td>• Increase consumption of fruits, vegetables, meats and dairy goods that are naturally high in target nutrients</td>
<td>• Provide nutrients in the form of pharmaceutical preparations (capsules, tablets, syrups)</td>
<td>• Target nutrients are added to foods as they are being processed</td>
<td>• Breed or genetically modify crops to increase their nutritional value</td>
</tr>
<tr>
<td>Examples</td>
<td>Leafy greens as source of Vitamin A</td>
<td>Twice yearly Vitamin A capsules for preschool children</td>
<td>Vitamin D in milk</td>
<td>Golden rice</td>
</tr>
<tr>
<td>Caveats</td>
<td>Requires longer time horizon to achieve results; Changing consumer tastes/preferences can be very difficult</td>
<td>Difficult to reach rural poor, where healthcare systems are underdeveloped</td>
<td>Rural poor have limited access to fortified foods</td>
<td>Significant upfront costs; minor ongoing costs to maintain traits in crops</td>
</tr>
<tr>
<td></td>
<td>Significant upfront costs; minor ongoing costs to maintain traits in crops</td>
<td>Recurring costs</td>
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<td>Uptake will depend on access that poor have to modified seed</td>
</tr>
<tr>
<td></td>
<td>There can be resistance to changed characteristics of familiar foods (e.g. color)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: “Why Biofortification Makes Sense” (http://www.harvestplus.org/content/learn-more); “Biofortification, biodiversity and diet: A search for complementary applications against poverty and malnutrition” (Johns and Eyzaguirre, 2006); “Assessing the Potential for Food-Based Strategies” (Ruel 2000)
Preliminary data suggests that biofortification could be more cost effective than dietary diversity for increasing Vitamin A consumption.

**Cost per DALY saved due to increased Vitamin A consumption ($)**

Wide ranges reflect uncertainty about full cost of biofortification programs.

**Cost of Vitamin A interventions in Guatemala ($)**

Does not take into account recurring costs associated with fortification and supplementation.

Note: Biofortification estimates are based on HarvestPlus calculations; DALY = Disability Adjusted Life Year.
However, there is still a strong case to be made for horticulture given the many challenges/drawbacks to biofortification

- **Access**
  - Biofortified seeds may be inaccessible to poorest farmers due to cost/availability
  - Lack of information about production techniques may limit yields that poor farmers obtain from biofortified varieties

- **Dietary simplification**
  - Biofortification only addresses symptoms of malnutrition (a particular nutrient deficiency); human health depends on many different inputs including fiber, antioxidants, immunomodulators, glycemic agents, etc.
  - There are complex interactions between nutrients that supplementation/fortification cannot address (e.g. Vitamin A and lipids)
  - Dietary diversity is the only solution that addresses the “double burden” of malnutrition (both underconsumption and overconsumption)

- **Biodiversity**
  - Emphasis on a short list of biofortified crops is likely to reduce land that is available to minor crops
  - Resulting loss in biodiversity will remove an important buffer against change (e.g. weather, pests, disease)

- **Demand**
  - Consumer acceptance of biofortified varieties is not guaranteed (e.g. in Africa and Central America, varieties of maize with high levels of β-carotene have not been adopted due to cultural reasons)
  - Research has shown that dietary diversity is the desire of poor people themselves (Bouis 2003)

Source: “Biofortification, biodiversity and diet: A search for complementary applications against poverty and malnutrition” (Johns and Eyzaguirre, 2006); Interview with Ray-Yu Yang (AVRDC)