Impact of environmental stressors on fruit and vegetable quality & yield

Relevance for future diets and population health

Improving health worldwide

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Environmental stressors

Reduced water availability, increased CO$_2$ concentration & temperature

(IPCC, 2015)

Several other (combinations of) stressors – including increased O$_3$ concentrations, episodic weather events, pollination, land degradation, salinity, soil quality, etc.
Framework: Environmental change and F&V

Socio-economic and societal factors

Drivers of environmental change

Interventions and policies
- Research and development
- Government involvement

Intermediate outcomes
- Food and nutrition security

Food system activities
- Agriculture
  - Input production
  - Processing and trade
  - Consumption
  - Waste management

Final outcomes
- Nutritional health and well-being

Tuomisto, Scheelbeek, Chalabi et al., 2017 (Wellcome Res Open)
Environmental stressors & agriculture

Predicted yield changes (%) by 2050

- Sorghum
- Maize

Predicted changes (%) in zinc & iron concentration by 2050

- Zn
- Fe
- Protein
- Phytate

(Mysers et al, 2014)

(Knox et al. 2012)
High nutritional importance: in some areas nutritious value **difficult to replace** by other food group:

- Vitamins (A, C, etc.) and its precursors
- Iron
- Zinc
- Calcium
- Fibre

- Potassium
- Magnesium
- Folate
- Iodine
- Antioxidants (?)

**FUture Diets And Health**

*Focus on fruits and vegetables – their role in global diets*
Importance of the fruits and vegetables food group

% of total death attributable to dietary risk factors

- Low fruit
- High sodium
- Low nuts and seeds
- Low vegetables
- Low whole grains
- Low omega-3
- High processed meat
- Low fibre
- Low polyunsat. fat
- High trans fat
- High sweet drinks
- Low calcium
- Low milk
- High red meat

Additional deaths (1000s) (climate-change induced changes in diets)

- Underweight
- F&V cons.
- R. meat cons.
- Overweight
- Obesity
- Total

GBD (2015)
Springmann et al. (2016)
Systematic Reviews: Title, abstract and full-text screening

**Fruit and Vegetable Yield**

- **Initial Search (42534)**
  - CAB Abstract: 14180
  - EMBASE: 2298
  - GreenFile: 825
  - AGRIS: 3996
  - Scopus: 5190
  - Web of Science: 10640
  - MEDLINE: 5405
- **Duplicates (5475)**
- **Title & Abstracts Screened (37059)**
- **Removed (36397)**
- **Full text reads (662)**
- **Excluded (467)**
  - Not relevant outcome
  - Unsuitable study method
  - Language
  - Unobtainable papers
- **Included in review (195)**

**Fruit and Vegetable Nutritional Quality**

- **Initial Search (31079)**
  - CAB Abstract: 3919
  - EMBASE: 5728
  - GreenFile: 89
  - AGRIS: 3539
  - Scopus: 8204
  - Web of Science: 5340
  - MEDLINE: 4260
- **Duplicates (7616)**
- **Title & Abstracts Screened (23463)**
- **Removed (23121)**
- **Full text reads (342)**
- **Excluded (230)**
  - Not relevant outcome
  - Unsuitable study method
  - Language
  - Unobtainable papers
- **Included in review (112)**
Geographical Spread of Studies

Distribution of study locations:
Studies investigating the effect of different environmental stressors on fruits and vegetable yield and quality

- Yellow: Crop yield: studies evaluating change in CO2 concentration
- Red: Crop yield: studies evaluating change in temperature
- Blue triangle: Crop yield: studies evaluating change in water availability
- Green: Nutritional quality: Studies evaluating change in water availability & change in CO2 concentration
Results 1a: *impact reduced water availability on crop yield*

<table>
<thead>
<tr>
<th>Crop type &amp; author</th>
<th>Effect (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solanum</td>
<td></td>
</tr>
<tr>
<td>Kumar et al 2015</td>
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<tr>
<td>Sun et al 2014</td>
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<td>Sun et al 2014</td>
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<tr>
<td>Veit-Kohler et al 1999</td>
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<tr>
<td>Subtotal (I-squared = 96.0%, p = 0.000)</td>
<td>-14.63 (-42.94, 13.67)</td>
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<tr>
<td>Cucurbits</td>
<td></td>
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<tr>
<td>Abd El-Mageed &amp; Semida 2015</td>
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<tr>
<td>Subtotal (I-squared = 98.5%, p = 0.000)</td>
<td>-7.45 (-15.26, 0.35)</td>
</tr>
<tr>
<td>Citrus</td>
<td></td>
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<tr>
<td>Roccuzzo et al 2016</td>
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<tr>
<td>Subtotal (I-squared = 73.5%, p = 0.052)</td>
<td>-11.64 (-22.77, -0.51)</td>
</tr>
<tr>
<td>Berries</td>
<td></td>
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<tr>
<td>Costello &amp; Patterson 2012</td>
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<tr>
<td>Subtotal (I-squared = 99.9%, p = 0.000)</td>
<td>16.20 (15.30, 17.09)</td>
</tr>
</tbody>
</table>

Percentage change in yield per 50% reduction in water availability
Results 1b: impact reduced water availability on nutritional quality of crops

% change in Vitamin C concentration per 50% decrease in water availability

Crop type & author                           Effect (95% CI)

Solanum
Barbagallo, 2012                             9.72 (5.60, 13.64)
Kumar, 2015                                  81.84 (76.58, 87.32)
Sun, 2014                                    13.46 (12.32, 15.60)
Sánchez-Rodríguez, 2010                     26.02 (25.60, 26.89)
Sánchez-Rodríguez, 2010                     18.40 (17.18, 19.64)
Sánchez-Rodríguez, 2010                     8.02 (8.88, 9.06)
Sánchez-Rodríguez, 2010                     6.76 (6.68, 6.84)
Veit-Kohler, 1990                            33.00 (32.95, 33.06)
Subtotal (I-squared = 100.0%, p = 0.000)    51.65 (51.75, 51.56)

Citrus
Roccuzzo, 2016                               12.23 (12.16, 12.31)
Roccuzzo, 2016                               7.55 (7.23, 7.87)
Roccuzzo, 2016                               5.96 (5.82, 6.10)
Subtotal (I-squared = 99.8%, p = 0.000)      12.80 (12.73, 12.86)

Drupe
Buenda, 2008                                 5.99 (4.07, 7.91)
Buenda, 2008                                 18.54 (18.02, 18.56)
Subtotal (I-squared = 100.0%, p = 0.000)    18.54 (18.02, 18.56)

Heterogeneity between groups: p = 0.000
Overall (I-squared = 100.0%, p = 0.000)

% change in carotenoids concentration per 50% decrease in water availability

Crop type & author                           Effect (95% CI)

Solanum
Barbagallo, 2012                             -6.18 (-6.29, -6.06)
Barbagallo, 2012                             -7.26 (-6.84, -5.68)
Pek, 2014                                    20.96 (20.89, 21.02)
Pek, 2014                                    -3.11 (-3.28, -2.92)
Pek, 2014                                    -6.68 (-6.90, -6.45)
Pek, 2014                                    40.12 (39.92, 40.31)
Pek, 2014                                    -6.17 (-6.37, -5.98)
Pek, 2014                                    -12.50 (-12.71, -12.48)
Pek, 2014                                    -6.25 (-6.29, -6.21)
Pek, 2014                                    -4.96 (-5.45, -4.47)
Pek, 2014                                    14.75 (10.06, 19.43)
Pek, 2014                                    48.08 (47.80, 48.35)
Pek, 2014                                    15.17 (15.30, 30.65)
Pek, 2014                                    12.91 (-6.10, 31.93)
Pek, 2014                                    -17.86 (-17.99, -17.76)
Pek, 2014                                    35.42 (35.41, 35.43)
Pek, 2014                                    3.62 (3.37, 3.88)
Pek, 2014                                    48.00 (45.96, 49.04)
Pek, 2014                                    -2.80 (-4.12, -1.49)
Pek, 2014                                    16.64 (10.57, 10.71)
Subtotal (I-squared = 100.0%, p = 0.000)    11.81 (11.80, 11.82)

Drupe
Buenda, 2008                                 -1.50 (-1.51, -1.49)
Buenda, 2008                                 -22.22 (-24.84, -19.61)
Buenda, 2008                                 15.56 (-8.89, 49.78)
Buenda, 2008                                 -17.35 (-19.15, -15.50)
Subtotal (I-squared = 88.8%, p = 0.000)      11.81 (11.80, 11.82)

Heterogeneity between groups: p = 0.000
Overall (I-squared = 100.0%, p = 0.000)
Results 2:

**impact increased temperature on yield**

- Legumes
  - within
  - within-above
  - below-within

- Leafy vegetables
  - within
  - within-above

- Solanum
  - within
  - within-above

- Root vegetables
  - within
  - within-above

- Berries
  - within
  - within-above

- Pome
  - below-within

**Percentage change in yield per 2.5°C increase in temperature**

- Wurr, 2000
- Xiao, 2009
- Jifon & Wolfe, 2005
- Prasad, 2002
- Xiao, 2009
- Wurr, 1996
- Choi, 2011
- Choi, 2011
- He, 2010
- Rodriguez, 2015
- Adams, 2001
- Rahman, 2000
- Choi, 2011
- Le Miere, 1998
- Sadras & Moran, 2013
- Kizildeniz, 2015
- Sun, 2012
- Ledesma et al, 2008
- Han, 2012
Results 3a:

*impact increased CO$_2$ concentration on crop yield*
Results 3b: **impact increased CO₂ concentration on nutritional quality of crops**

Very small number of studies, however some indications:

- Marginal decreases in zinc and Vitamin C concentration in Solanum crops
- For leafy vegetables: potential marginal decreases in iron
- For Solanum crops: potential marginal increases in iron

**Crop type & author**

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<td>Khan, 2013</td>
<td>-5.40 (-5.60, -5.20)</td>
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<tr>
<td>Khan, 2013</td>
<td>-7.16 (7.34, -6.98)</td>
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Subtotal (I-squared = 99.9%, p = 0.000)

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<td>Leafy vegetables</td>
<td></td>
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<tr>
<td>Jain, 2007</td>
<td>-2.96 (-3.15, -2.78)</td>
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<tr>
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<tr>
<td>Khan, 2013</td>
<td>11.30 (11.03, 11.57)</td>
</tr>
<tr>
<td>Khan, 2013</td>
<td>2.83 (2.48, 3.19)</td>
</tr>
</tbody>
</table>

Subtotal (I-squared = 99.9%, p = 0.000)

**Change in zinc concentration (μg/g fruit weight) per 150 ppm increase in CO₂ concentration**

**Change in iron concentration (μg/g fruit weight) per 150 ppm increase in CO₂ concentration**
Results in context

Vitamin A, Vitamin C, Zinc & Iron deficiency (prevalence) combined

Bodnar, 2013

Miller et al. (2016)
Discussion & possible implications

- Considerable influence of environmental change on fruit and vegetable yield and nutritional quality
  - Effects on yield predominantly negative - effects on quality predominantly positive (marginal effect)
  - Effects of increased CO₂ concentration exception
  - Study quality varies

- Effects likely to be most noticeable in already food-scarce areas – where substitution possibilities are limited.
  - need to study likelihood that this could lead to crucial nutrient deficiencies – Equity

- Call to act!
  ✓ Further quantify effects – interaction of stressors
  ✓ impact of adaptation strategies
  ✓ Place of fruits and vegetables in total diet - substitution behaviour
  ✓ where and how to intervene to minimise potential impact on nutrition related chronic diseases and micronutrient deficiencies

- Something to keep in mind: potentially important topic in climate change-health nexus!
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Majid Ezzati

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