Introduction

• What is biofortification?
• Breeding food crops for higher contents of essential micronutrients (vitamins & minerals)
• Why biofortification?
• Micronutrient malnutrition affects billions of people world-wide
• Biofortification is potentially cheaper than alternative interventions (fortification & supplementation)
Introduction

- Why is iron deficiency bad?
- Functional outcomes of iron deficiency anaemia (IDA) are:
  - impaired physical activity
  - impaired mental development
  - increased maternal mortality
  - stillbirths due to maternal death
  - child deaths due to lack of breastfeeding

Quantifying health benefits

- Health improvements result in reduced mortality or in reduced morbidity
- Morbidity can be weighted to be comparable with premature mortality
- The “burden” of a disease is then the
  - years of life lost (YLL) due to mortality
  - years lived with disability (YLD)
- Or: disability-adjusted life years (DALYs)
  - Burden = DALY_{lost} = YLL + YLD
Quantifying health benefits

More formally:

$$DALYs_{lost} = \sum_j T_j M_j \left( \frac{1-e^{-rL_j}}{r} \right) + \sum_i \sum_j T_j I_{ij} D_{ij} \left( \frac{1-e^{-rd_{ij}}}{r} \right)$$

- $T_j$ = size of target group $j$
- $M_j$ = mortality rate due to IDA in target group $j$
- $L_j$ = remaining life expectancy for target group $j$
- $r$ = discount rate of 3 percent
- $I_{ij}$ = incidence rate of disease $i$ in target group $j$
- $D_{ij}$ = disability weight of disease $i$ in target group $j$
- $d_{ij}$ = duration of disease $i$ in target group $j$

Current situation in India

- Some prevalence rates used:

<table>
<thead>
<tr>
<th>Target groups</th>
<th>Moderate IDA</th>
<th>Severe IDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children ≤ 5 yrs</td>
<td>27.5 %</td>
<td>3.2 %</td>
</tr>
<tr>
<td>Women ≥ 15 yrs</td>
<td>7.4 %</td>
<td>1.0 %</td>
</tr>
</tbody>
</table>

- IDA-related maternal mortality: 5% of total maternal mortality
- The current burden of IDA in India is $0.2m$ YLL + $3.7m$ YLD = 4m DALYs$_{lost}$
Current situation in India

- Available interventions
  - Medical supplementation (iron pills)
  - Industrial fortification (enriched flour)
  - Food-based approaches (education)

- Biofortification
  - Wide potential coverage
  - Self-targeting if focussed on staples
  - Targeting of rural populations
  - Continuous benefit stream

Potential impact of biofortification

Assumptions used to calculate impact

<table>
<thead>
<tr>
<th></th>
<th>Iron-rich rice</th>
<th>Iron-rich wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Fe content</td>
<td>3 ppm</td>
<td>38 ppm</td>
</tr>
<tr>
<td>Potential Fe content</td>
<td>6 ppm</td>
<td>46 ppm</td>
</tr>
<tr>
<td>Potential increase</td>
<td>100 %</td>
<td>20 %</td>
</tr>
<tr>
<td>Consumption share</td>
<td>20 %</td>
<td>30 %</td>
</tr>
</tbody>
</table>
Potential impact of biofortification

**Status quo**

- Food consumption data of 140,000 households

DALYs lost due to IDA

Prevalence rate of IDA

Iron intake

“with biofortification”

DALYs lost due to IDA

Prevalence rate of IDA

Iron intake

Potential impact

1. 6.5%
2. 23.5%
3. 3.0%
4. 16.5%
5. 7.4%
6. 6.5%
7. 3.0%

New prevalence rates for moderate IDA

Target groups

<table>
<thead>
<tr>
<th>Children ≤ 5 yrs</th>
<th>Old</th>
<th>Pessimist.</th>
<th>Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.5 %</td>
<td>23.5 %</td>
<td>16.5 %</td>
<td></td>
</tr>
<tr>
<td>7.4 %</td>
<td>6.5 %</td>
<td>3.0 %</td>
<td></td>
</tr>
</tbody>
</table>

Reductions in the burden of IDA in India

<table>
<thead>
<tr>
<th>Biofortification of</th>
<th>Scenario</th>
<th>DALYs saved</th>
<th>Decrease of burden</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice &amp; wheat</td>
<td>pessim.</td>
<td>0.8 m</td>
<td>- 19 %</td>
</tr>
<tr>
<td>Rice &amp; wheat</td>
<td>optimist.</td>
<td>2.3 m</td>
<td>- 58 %</td>
</tr>
</tbody>
</table>
Economic evaluation

• With only limited resources available “effectiveness” is a poor yardstick

• To “compete” with alternatives biofortification has to “pay off”

• Juxtaposing DALYs saved with R&D costs yields “Cost per DALY”

• The cost per healthy life year can be compared with other interventions

Economic evaluation

• Annual costs for both iron-rich rice & wheat range from $0.2m - $1.6m

• The annual average over 30 years for both crops ranges from $0.3m - $0.6m

• **Only** the pills to reach 50% of all pregnant women and children aged 1-5 years with iron supplements would cost $5.2m **each** year
Economic evaluation

- Cost-effectiveness of iron biofortification

<table>
<thead>
<tr>
<th>Target crop</th>
<th>Rice &amp; wheat</th>
<th>Only rice</th>
<th>Only wheat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pessimistic scenario</td>
<td>3.53</td>
<td>2.44</td>
<td>6.01</td>
</tr>
<tr>
<td>Optimistic scenario</td>
<td>0.48</td>
<td>0.32</td>
<td>0.66</td>
</tr>
</tbody>
</table>

- Saving one healthy life year can cost as little as 32 Cents

The World Development Report 1993 classifies costs per DALY:
- $ 1 - $ 3 = “most cost-effective”
- < $ 25 = “remarkably low”
- $ 50 - $ 150 = “highly cost-effective”
- Gillespie reports costs per DALY of iron fortification and supplementation in the range of $ 4.4 - $ 12.8
- This contrasts favourably with our results of $ 0.48 - $ 3.53
Economic evaluation

1. For comparing results with other interventions or to reach decision makers who are not familiar with DALYs
2. Cost-benefit analyses can be carried out by attaching a $ value to one DALY
3. In the pessimistic scenario biofortifying both crops has an IRR of 63% and a benefit-cost ratio of 142.
4. In the optimistic case the IRR is 141% and the BCR is 1042.

Evaluation

Other studies of iron interventions, using different approaches, yielded results in the range of

- BCR = 1.6-59 for supplementation
- BCR = 5-200 for fortification
- BCR = 19-79 for biofortification

- Again, this contrasts favourably with our BCR of 142-1042
Conclusion

- Biofortification is potentially effective in reducing the burden of IDA in India
- Biofortification ranks amongst the “cheapest” micronutrient interventions, costing only $3.53 per DALY saved
- Where hidden hunger is wide-spread, breeding for micronutrient-rich crops is an economically viable intervention

Conclusion

- This study provides valuable input for decision makers
- We further extended the use of “DALYs” to assess output of agricultural research
- We developed a new framework to analyse biofortification and iron def.
- And, as a first, we used representative national household data to generate the basis for this kind of impact analysis
Thank you
for your attention!