Within-Species Genetic Variation in Leaf Magnesium Concentration in Forage Grasses

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E. Louise Ander, Nick A. Beresford, Neil M.J. Crout, Neil S. Graham, J. Alan Lovatt, Sue Walker, Michael Watts, Philip J. White, Scott D. Young, Martin R. Broadley
Structure of talk

1. Global Mg supplies and deficiency risks
2. National Mg intakes
3. Breeding potential in crops (forage grass and brassica)
4. Breeding vs fertilisers?
Global Mg supplies

Supply = Food Balance Sheet * Food Composition Table

Food & Agriculture Organization Food Balance Sheets (FBSs):
94 food items, 145 countries (>1m), 1992-2011 (FAOSTAT)

FBSs are net supply at household level, adjusted for edible portion

Food Composition Table (FCT) for Mg from US Dept. of Agriculture

Deficiency risks based on a ‘cut-point’ defined by requirements, assuming 25% variation in intake (inter-individual)
Estimated Average Requirement ‘cut-point’

\[ \text{LRNI} = \text{Estimated Average Requirement} \]
\[ \text{(L)RNI} = \text{(Lower) Reference Nutrient Intake} \]
Estimated Average Requirement ‘cut-point’

Risk of deficiency based on inadequate intake
Global Mg supply (2011)

Mg supply (mg capita \(^{-1}\) d \(^{-1}\))

- 340 - 478
- 478 - 587
- 587 - 715
- 715 - 944
- No data

Diriba B. Kumssa et al., in prep.
Global Mg deficiency risk (2011): WtdEAR=258 mg $\text{capita}^{-1} \text{d}^{-1}$

Diriba B. Kumssa et al., in prep.
Global Mg supply and deficiency risks (1992-2011)

Supplement (mg capita⁻¹ d⁻¹)  Deficiency risk (%)

<table>
<thead>
<tr>
<th>Region</th>
<th>Reference Year</th>
<th>1995</th>
<th>2000</th>
<th>2005</th>
<th>2010</th>
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<td>50</td>
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Legend:
- Eastern Africa
- Middle Africa
- Northern Africa
- Caribbean
- Central America
- Northern America
- Northern Europe
- South-Eastern Asia
- South Asia
- Southern Europe
- South America
- Western Asia
- Western Europe
- Australia and New Zealand

Diriba B. Kumssa et al., in prep.
Global Mg supply by food group (1992-2011): Africa

Diriba B. Kumssa et al., in prep.
Global Mg supply by food group (1992-2011): Americas

Diriba B. Kumssa et al., in prep.
Global Mg supply by food group (1992-2011): Europe

Diriba B. Kumssa et al., in prep.
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National Mg supply (UK)

2008/09 - 2011/12

UK energy supply (FAO FBS) in 2011: 3414 kcal capita\(^{-1}\) d\(^{-1}\)

UK Mg deficiency risk (FAO FBS) in 2011: 1.5\% (~600 mg capita\(^{-1}\) d\(^{-1}\))

Mg intakes from rolling National Diet & Nutrition Survey (NDNS):
11\% females, 16\% males, 19-64 <LRNI 150/190 mg d\(^{-1}\)
53\% females, 28\% males, 11-18 <LRNI ~190 mg d\(^{-1}\)

(Under?)-reported energy intakes from NDNS:

females 19-64: 1613 (455)
females 11-18: 1569 (423)

males 19-64: 2111 (617)
males 11-18: 1972 (518)

Edward J.M. Joy, Diriba B. Kumssa et al., in prep.
National Mg supply (Malawi)

Food data from Malawi Third Integrated Household Survey (IHS3)

>12,500 households interviewed in 2010-11

Food consumption module: households asked to recall foods consumed in past 7 d from 112 items (e.g. ‘Maize ufa refined (fine flour)’, ‘Dried fish’)
Dietary intake surveys in Malawi

**MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK**

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**CODES FOR UNIT:**
- KILOGRAMME............................................1
- 50 KG. BAG...........................................2
- 90 KG. BAG............................................3
- PAUL (SMALL)..........................................4
- PAUL (LARGE)...........................................5
- NO. 10 PLATE..........................................6
- NO. 12 PLATE..........................................7
- BUNCH..................................................8
- PIECE..................................................9
- HEAP...................................................10
- BALE...................................................11
- BASKET (DENGUE)......................................12
- BASKET (DENGUE)......................................13
- CK-CART (UNSHEDLED).................................14
- LITRE..................................................15
- CUP....................................................16
- TIN.....................................................17
- GRAM...................................................18
- MILLILITRE.............................................19
- TEASPOON...............................................20
- BASIN..................................................21
- SATCHET/TUBE..........................................22
- OTHER (SPECIFY).......................................23
National Mg supply (Malawi)

Food data from Malawi Third Integrated Household Survey (IHS3)

>12,500 households interviewed in 2010-11

Food consumption module: households asked to recall foods consumed in past 7 d from 112 items (e.g. ‘Maize ufa refined (fine flour)’, ‘Dried fish’)

Enumerators recorded the amount consumed and source (i.e. ‘own production’, ‘bought’ or ‘gift’)

Units include standard metrics (grams, litres etc.) and local units (small plate, large plate, small bucket, large bucket, basin etc.)

Food composition data from Joy et al. (2015)
Food composition data (Malawi): 97 food types

Joy et al. (2015)
Dietary Requirements for Magnesium but not Calcium are Likely to be met in Malawi Based on National Food Supply Data

Food composition data (Malawi): maize
Food composition data (Malawi)

Joy et al. (2015)
Risk of Mg deficiency is >> than predicted by FBSs

Percentage of households with Mg consumption < EAR (left) < RDA (right)

- < 5%
- 5 - 25%
- > 25%
- No data

Edward J.M. Joy, Diriba B. Kumssa et al., in prep.
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Breeding potential in forage grasses

Hypomagnesaemia-related conditions long-recognised in ruminants

Cows: 1-4% in Europe affected, 20-30% within individual herds

Sheep: 20-40 hypomagnesaemia outbreaks per year in the UK

Mg absorbed through rumen wall in ruminants, not in small intestine

Can occur at lactation due to increased Mg requirements; accompanied by / confused with, hypocalcaemia (milk fever), affecting ~7-8% of UK cows

Tetany (grass staggers) occurs in spring-time when grasses have low dry matter, high protein, high soluble carbohydrate, high K^+

Forages low in Mg due to genotypic factors, soil conditions / other cations

Feed supplements and fertilisers (calcined magnesite, MgO/MgCO₃; kieserite, MgSO₄; dolomitic limestone, CaCO₃.MgCO₃) used at high rates / costs
Grasses have inherently low Mg concentrations

- All other taxa (e.g. roses, legumes)
- Caryophyllales (e.g. sugar beet, carnation)
- Poales (e.g. the grass / cereal family, Poaceae)
- Asterales (e.g. the daisy / sunflower family Asteraceae)

Assessing variation in [Mg] among four grass species

- *Lolium perenne* (n=280)
- *Lolium multiflorum* (n=17)
- Hybrid ryegrass (n=101)
- *Festuca arundinacea* (n=10)

Beth Penrose et al., in prep.
Assessing variation in [Mg] among four grass species

Plots sown 2010-12

Beth Penrose et al., in prep.
Multiple cuts taken in 2013 and 2014
Multiple cuts taken in 2013 and 2014
Up to two-fold variation in leaf Mg concentrations among four species of forage grass

Arithmetic cultivar-means for all plots, ± 1 standard deviation.

Beth Penrose et al., in prep.
Consistency in leaf Mg concentrations and leaf ‘Tetany Index’ at different sites

55 varieties of forage grass (varietal means); a Tetany Index >2.2. is considered to lead to higher risks of hypomagnesaemia

Beth Penrose et al., in prep.
Breeding potential in forage grasses – revisited?


Breeding potential in *Brassica*

Phylogenetic analyses among angiosperms

Brassica have inherently high leaf Mg concentrations

Forward screens of chemically-mutagenised *Brassica*

- *Brassica rapa* R-o-18 tilling population (3464 M$_2$s, 4 WT, n=5)
- Leaf mineral concentration 3*siblings, ~30 elements*
Slightly-delayed flowering...

M₄ generation plants growing in the glasshouse
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Breeding or fertilisers for humans?

Cumulative probability

Magnesium intake (all sources, mg d⁻¹)

Mg females

Mg males

Current intake

+ 1 veg. (excl. potato)

“biofortified veg.” (+50%, + 50% & 2 veg.)

### Breeding or fertilisers for humans?

**Numbers of UK adults <LRNI to >LRNI as a consequence of intervention (2002 data)**

<table>
<thead>
<tr>
<th></th>
<th>+2 veg.</th>
<th>+50% biofort.</th>
<th>both</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>1.4m</td>
<td>2.0m</td>
<td>4.0m (75%)</td>
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