XVIth session of the

eurofins international seminar

Possibilities and limitations of using isotope & multi-element techniques to distinguish between 'Ecological' and 'Conventional' agricultural practices

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ifr Institute of Food Research

UEA NORWICH

- Background
  - social & economic context
  - scientific context
- Results
  - Stable nitrogen isotope analysis
  - Trace element analysis
- Conclusions
- Challenges for the future

- Consumer awareness
  - Mistrust of ‘conventional’ intensive farming methods – pesticides, herbicides, synthetic fertilisers, veterinary drugs ….
  - Purported health benefits
  - Concerns over animal welfare
  - Environmental concerns
  - Food miles

- The global organic food market grew by 13.6% in 2006 to reach a value of $36.7 billion.
- In 2011, the market is forecast to have a value of $67.1 billion, an increase of 83% since 2006.
- Fruit and vegetable sales form the most lucrative segment of the market, accounting for 39.5% of the market's value.
- The largest organic food market is the Americas, which accounts for 49.7% of the global market's value.

Source: 'Just Food' Market Research http://www.just-food.com/store/product.aspx?id=52543

The higher production costs associated with Organic agriculture

- Less intensive methods
- Lower yields
- Greater care of the farm environment
- Segregation of Organic Produce

= Premium retail prices

- Price differentials between conventional and Organic crops can vary as much as 20 to 250% depending on crop type e.g. wine, coffee and tea

= Economic incentives exist to mis-describe 'conventional' produce as 'Organic/Biological/Ecological'

Organic Farming

- Organic farming severely restricts the use of artificial chemical fertilisers and pesticides.
- Organic farmers rely on developing a healthy, fertile soil and growing a mixture of crops.
- Management practices which sustain soil health and fertility.
- The use of natural methods of pest, disease and weed control.
- High standards of animal welfare.
- Low levels of environmental pollution.
- Enhancement of the landscape, wildlife and wildlife habitat.
- The prohibition of all genetically engineered food and products.

Project Aim

To discover whether it is possible to discriminate between organically and conventionally grown crops using stable isotope and multi-element analysis.

Project Raison d'être

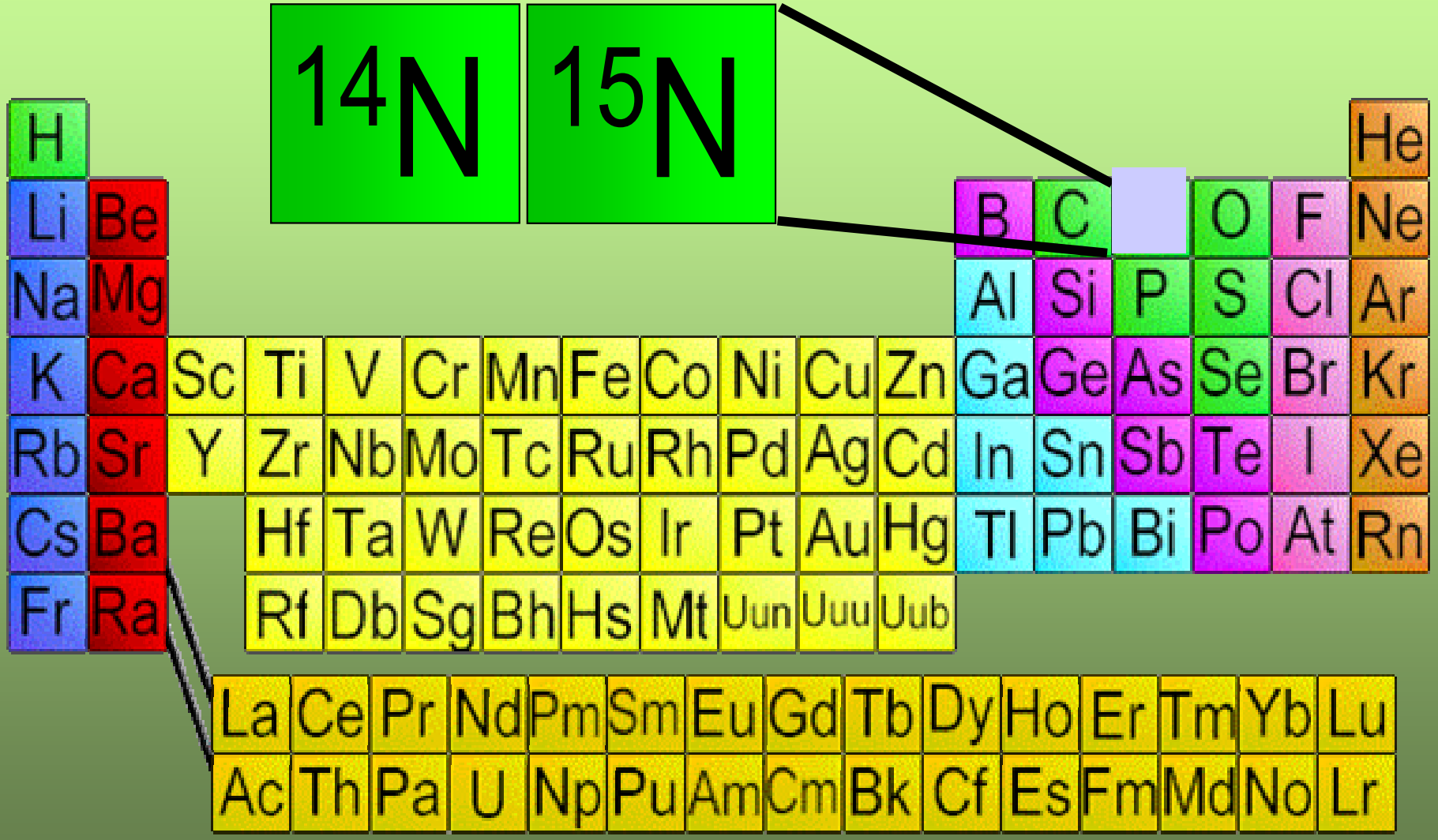
- **Prevention of food fraud**

Help prevent the mislabelling of conventionally cultivated produce as 'organic' by developing analytical methods to check off-the-shelf products

- **Protect the interests of the consumer**
- **Protect the interests of honest growers and traders**

Organic Fraud

“Can nitrogen isotope and TE analysis help us detect conventional crops that have been labelled as Organic?”

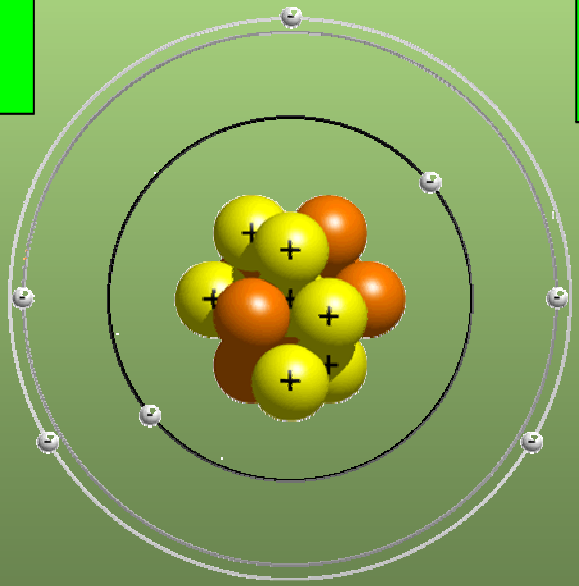


Bentor, Yinon. Chemical Element.com - Nitrogen. Apr. 21, 2004 <http://www.chemicalelements.com/elements/n.html>

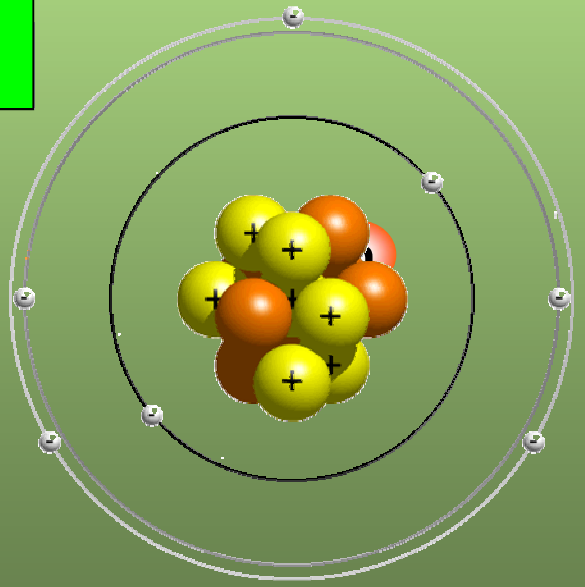
'light' isotope

'heavy' isotope

$^{14}_{7}N$



$^{15}_{7}N$

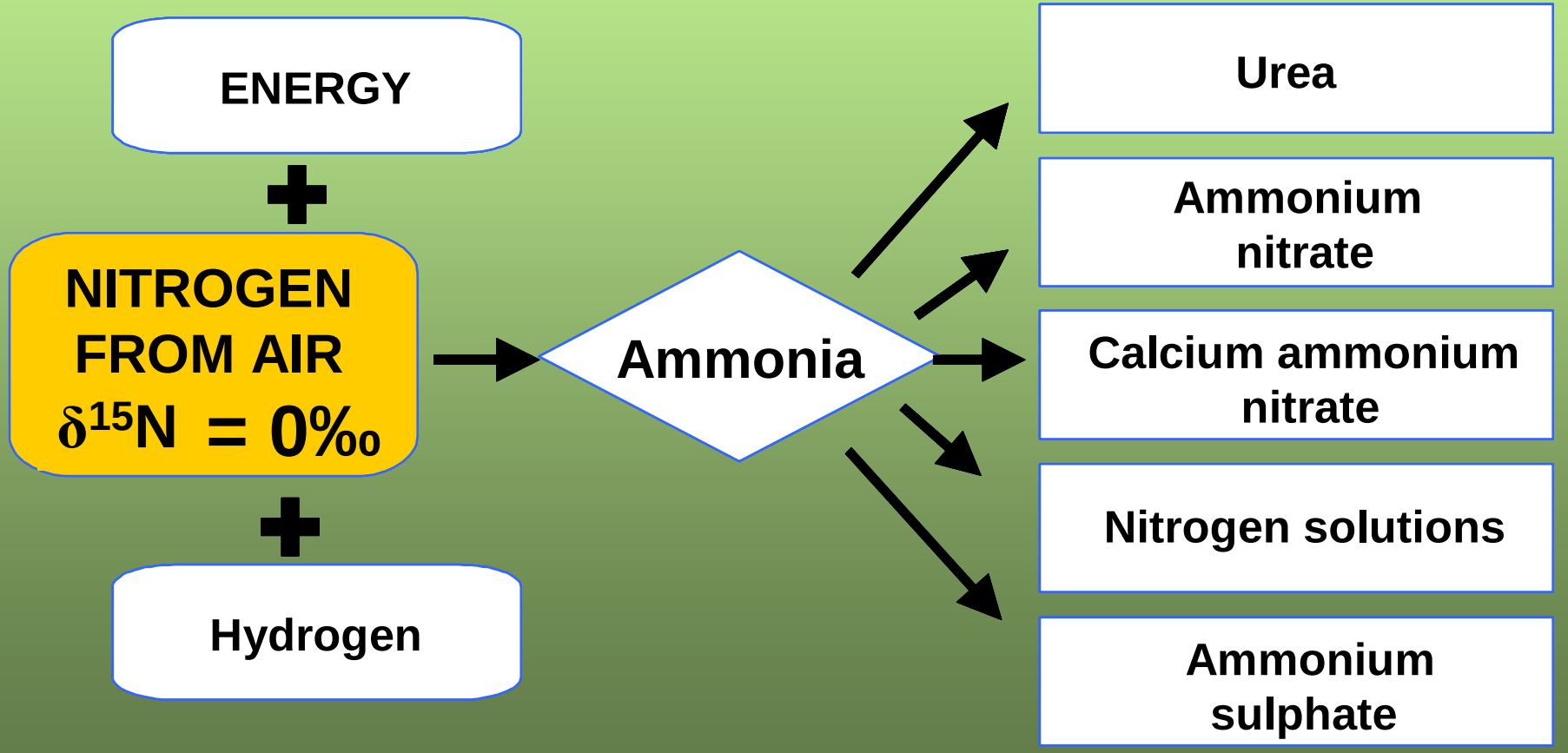


99.63 %

0.37 %

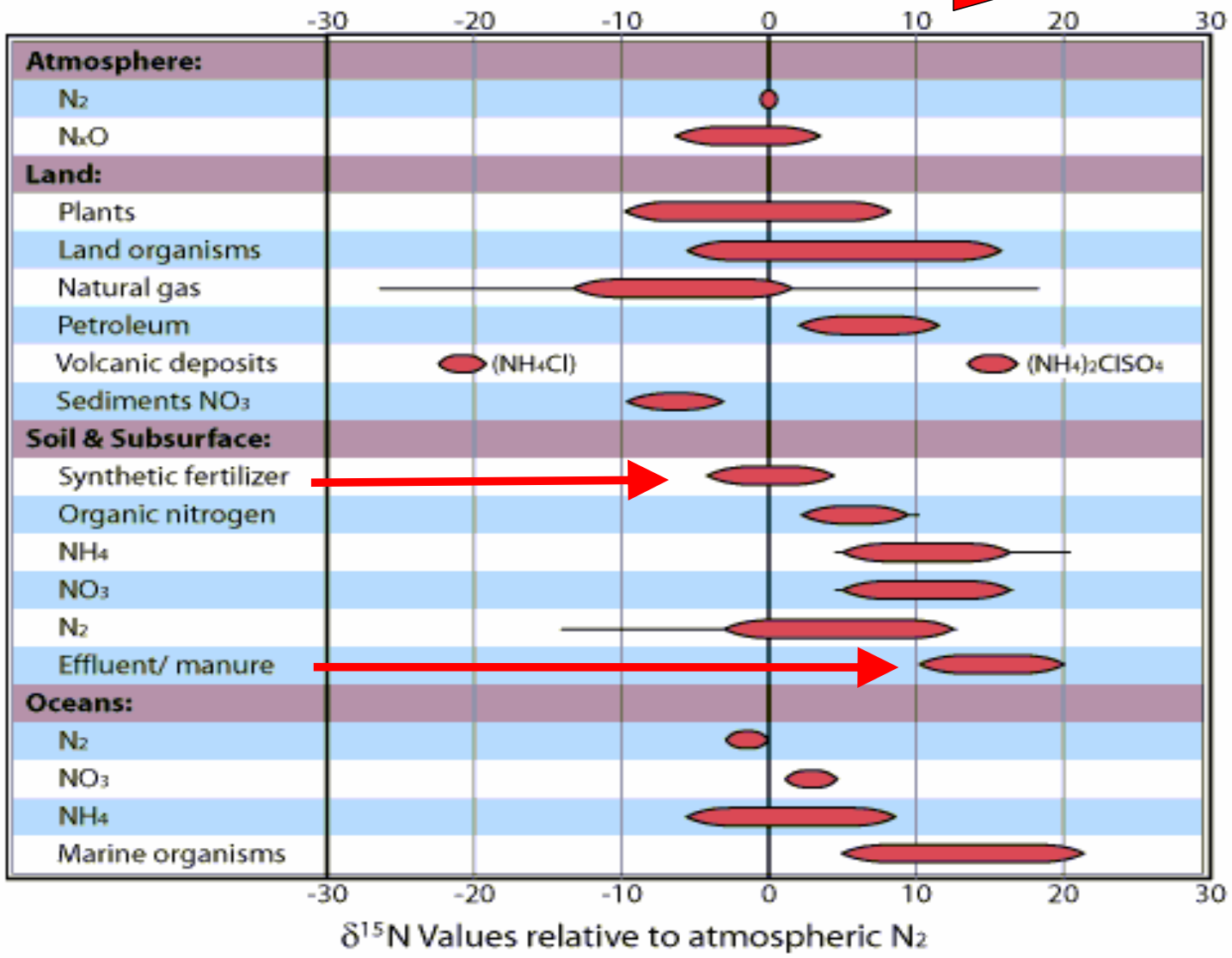
Chemical fertiliser production

Expect $\delta^{15}N$ = 0 ‰



^{14}N	^{15}N
14.00307	15.0001
99.63%	0.37%
Stable	Stable

Increasing ^{15}N content

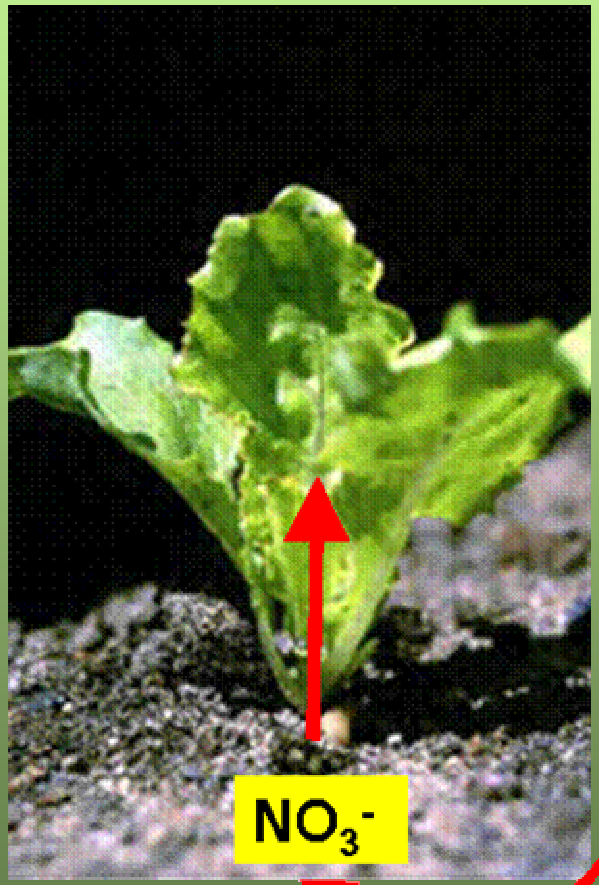


AS Bateman and SD Kelly (2007) Fertilizer nitrogen isotope signatures, *Isotopes in Environmental and Health Studies,* Vol. 43, No. 3, September 2007, 237–247

FROM: SAHRA

http://www.sahra.arizona.edu/programs/isotopes/nitrogen.html

Hypothesis



Input of Chemical Fertiliser (NO_3 or NH_4)

$-2‰ \leq \delta^{15}N \leq +2‰$

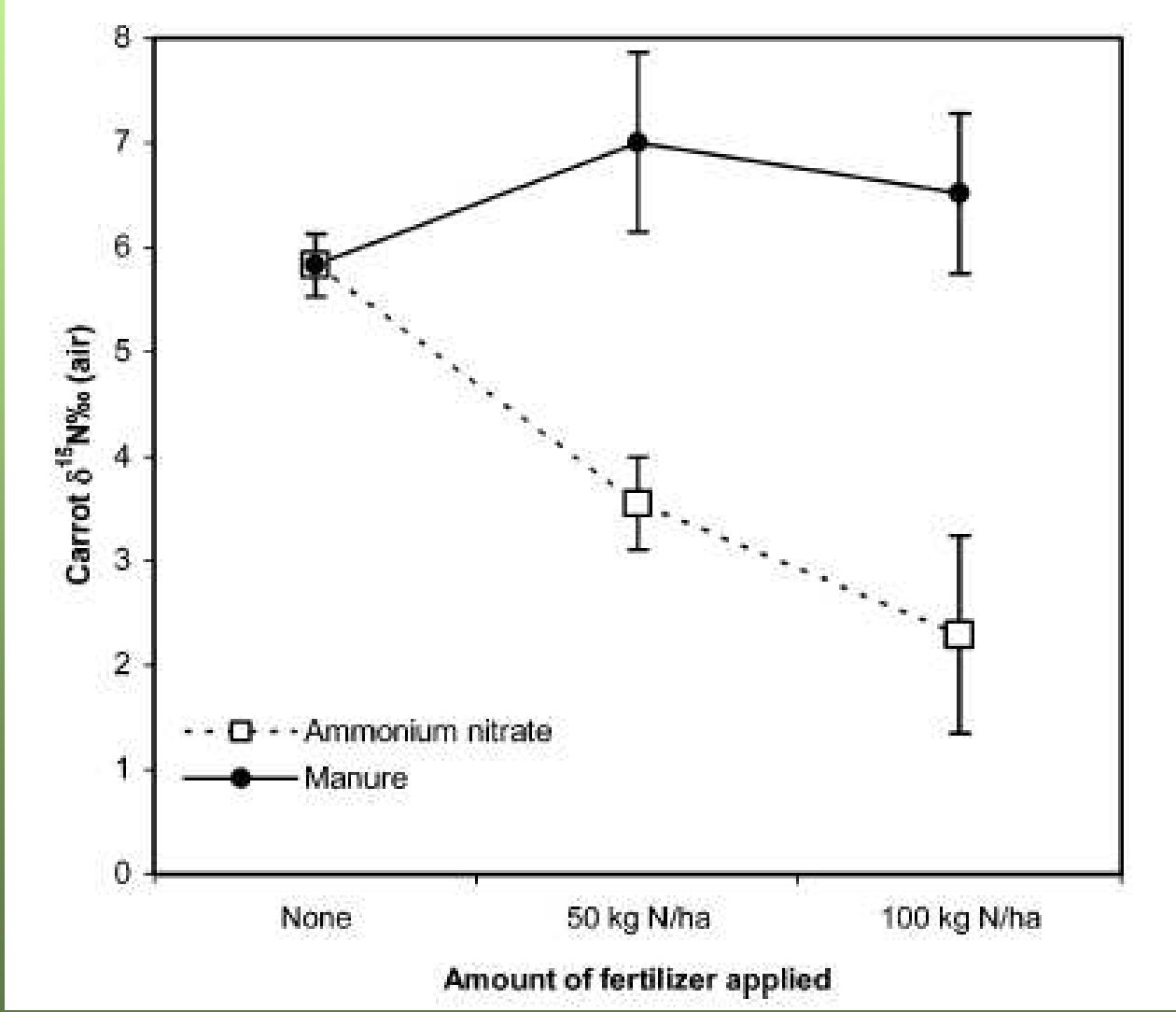
↓

Lower $\delta^{15}N$ of available soil nitrogen pool

↓

Plants with lower $\delta^{15}N$

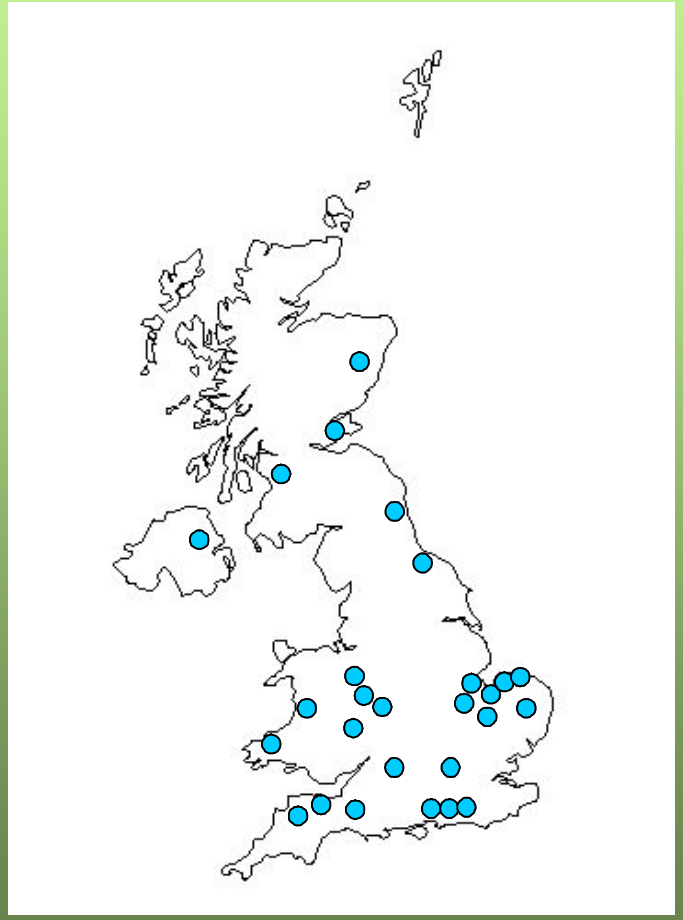
Controlled cultivation experiments



Carrot
Tomato
Lettuce
Mushroom

A S Bateman, S D Kelly & T D Jickells (2005)
"Nitrogen Isotope Relationships between Crops and Fertilizer: Implications for Using Nitrogen Isotope Analysis as an Indicator of Agricultural Regime"
Journal of Agricultural and Food Chemistry, 53(14); 5760-5765.

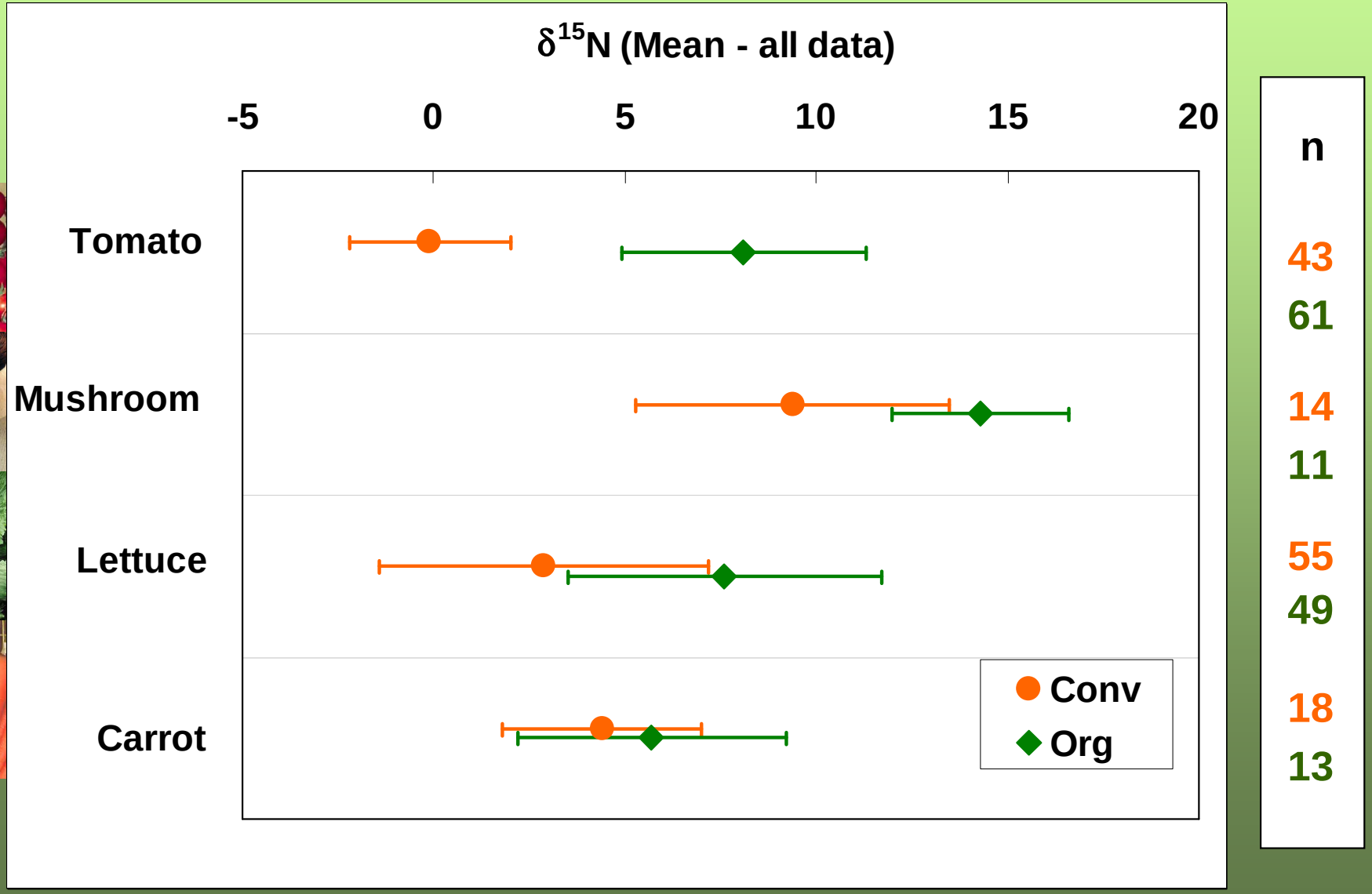
Baseline Survey



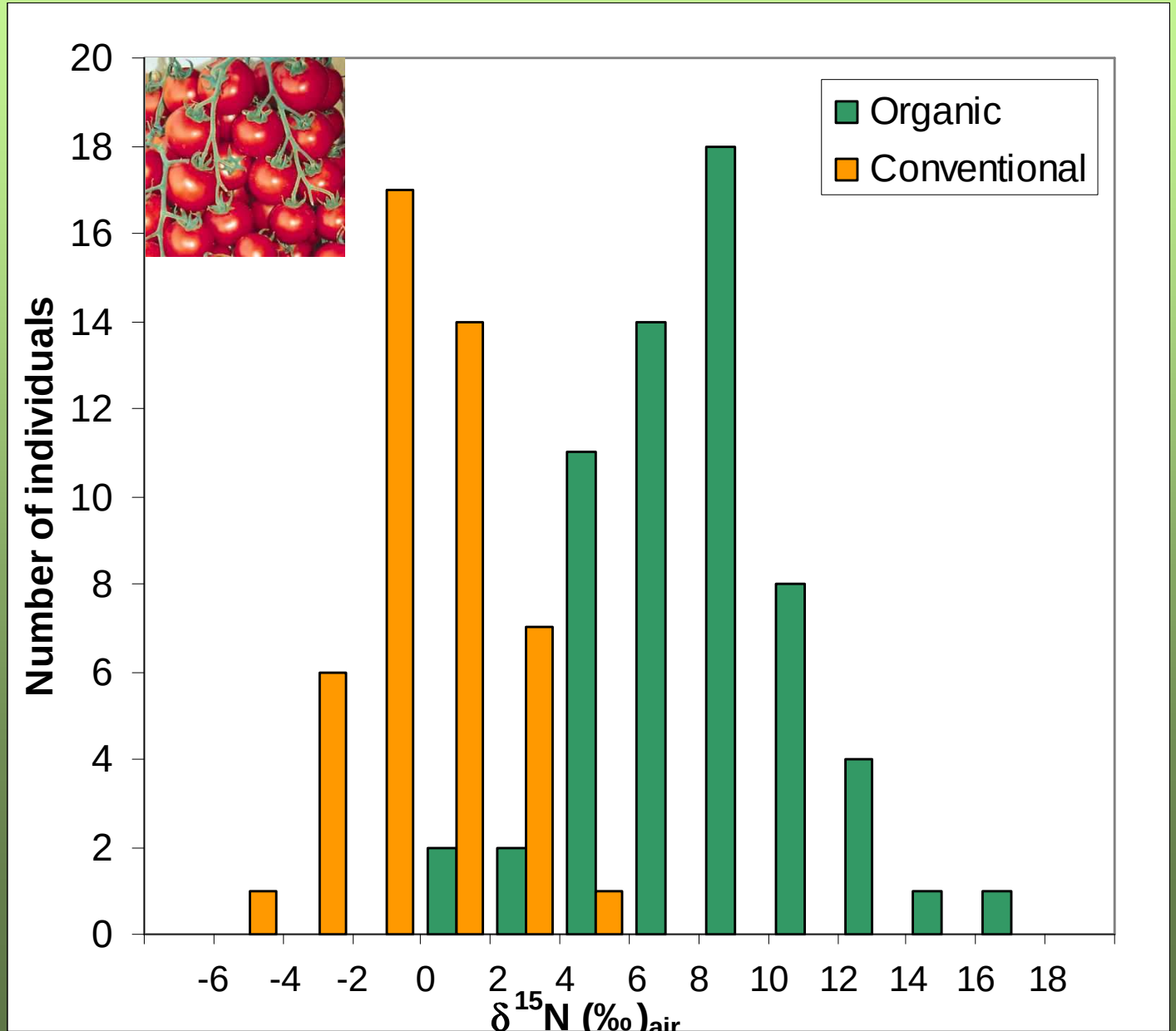
+ some samples from Italy, Germany, Spain & Holland

- Soil type
- Weather
- Time of harvest
- Type and $\delta^{15}N$ of synthetic fertiliser
- Type and $\delta^{15}N$ of fertiliser applied by organic grower

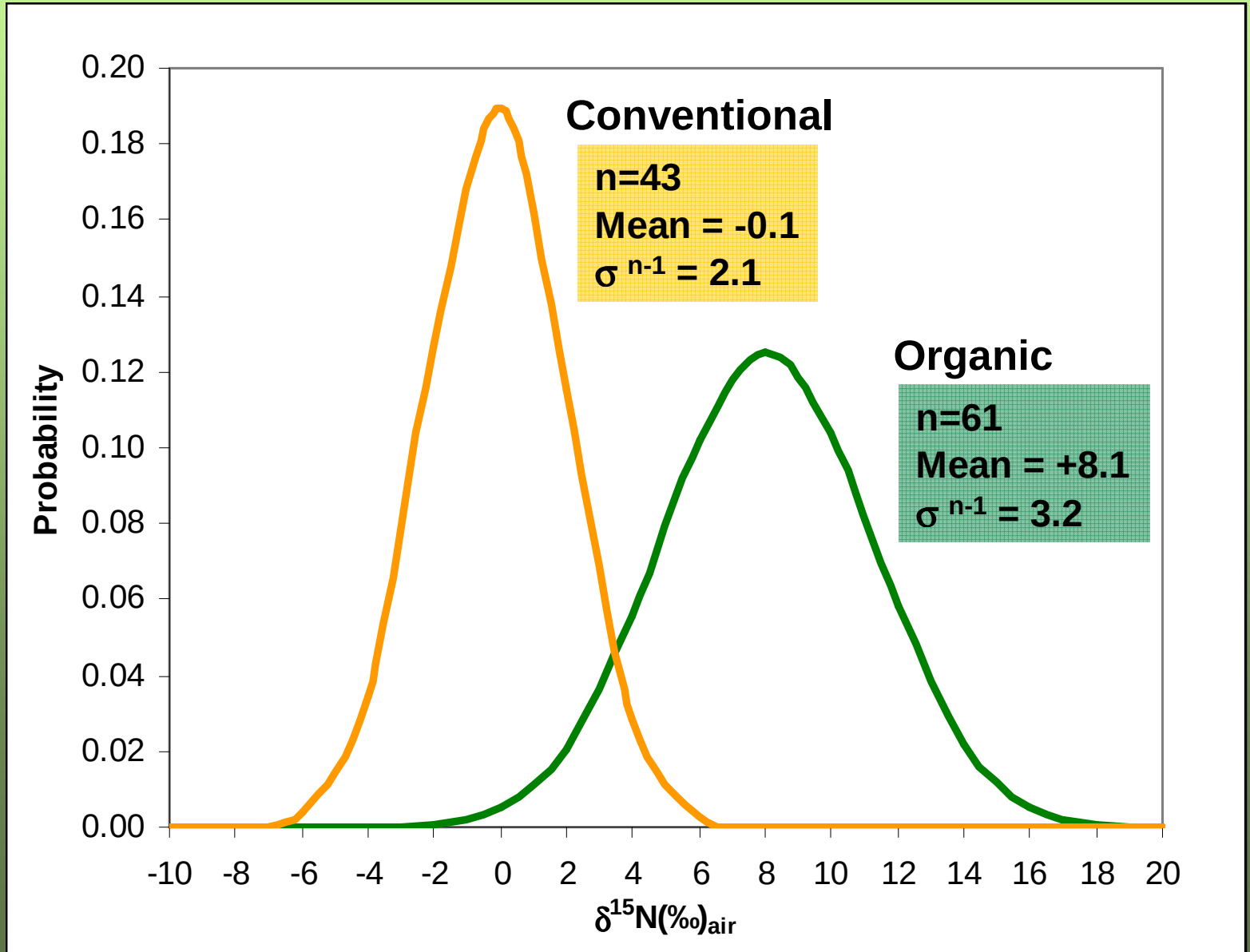
Baseline Survey – Summary data

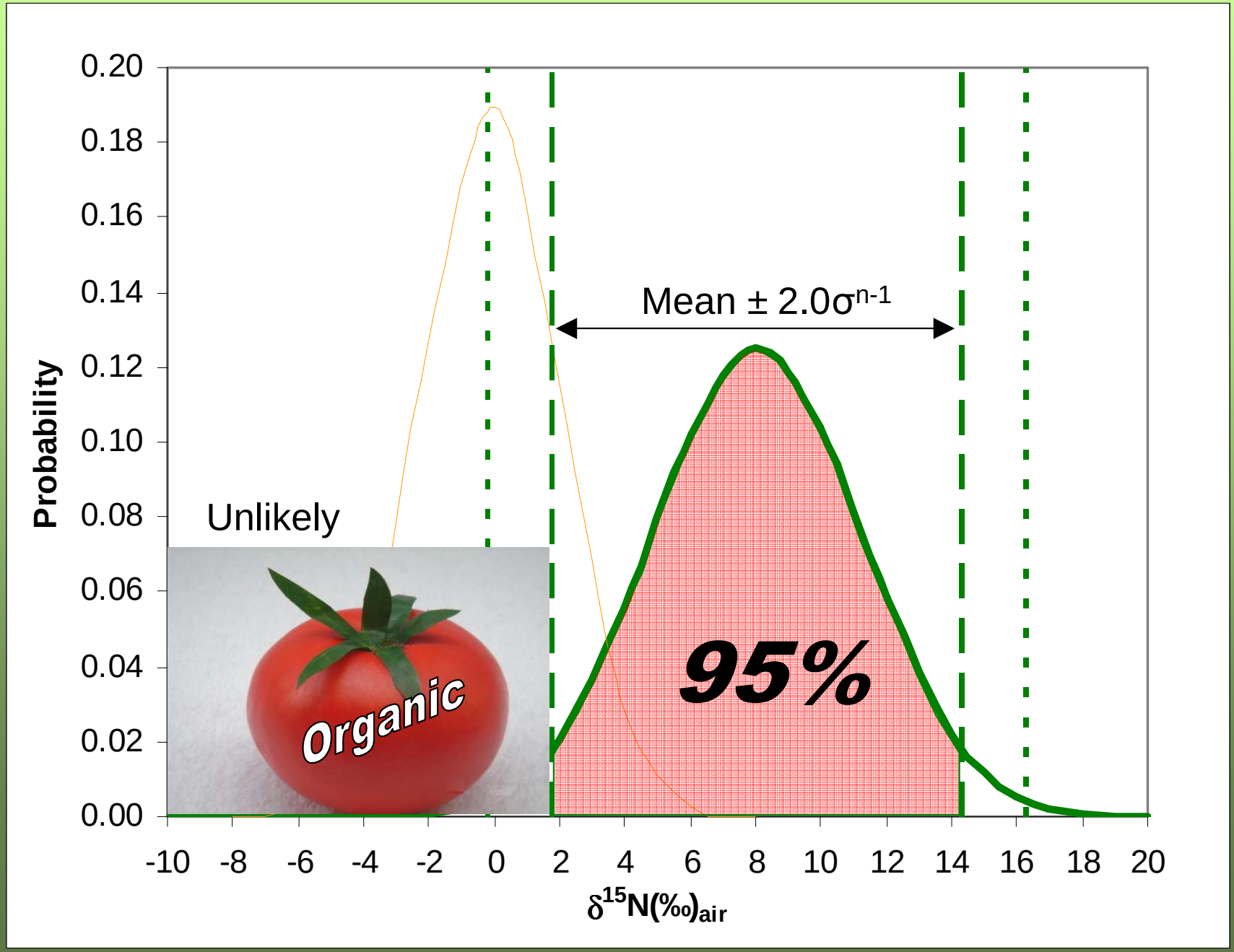


Tomato data

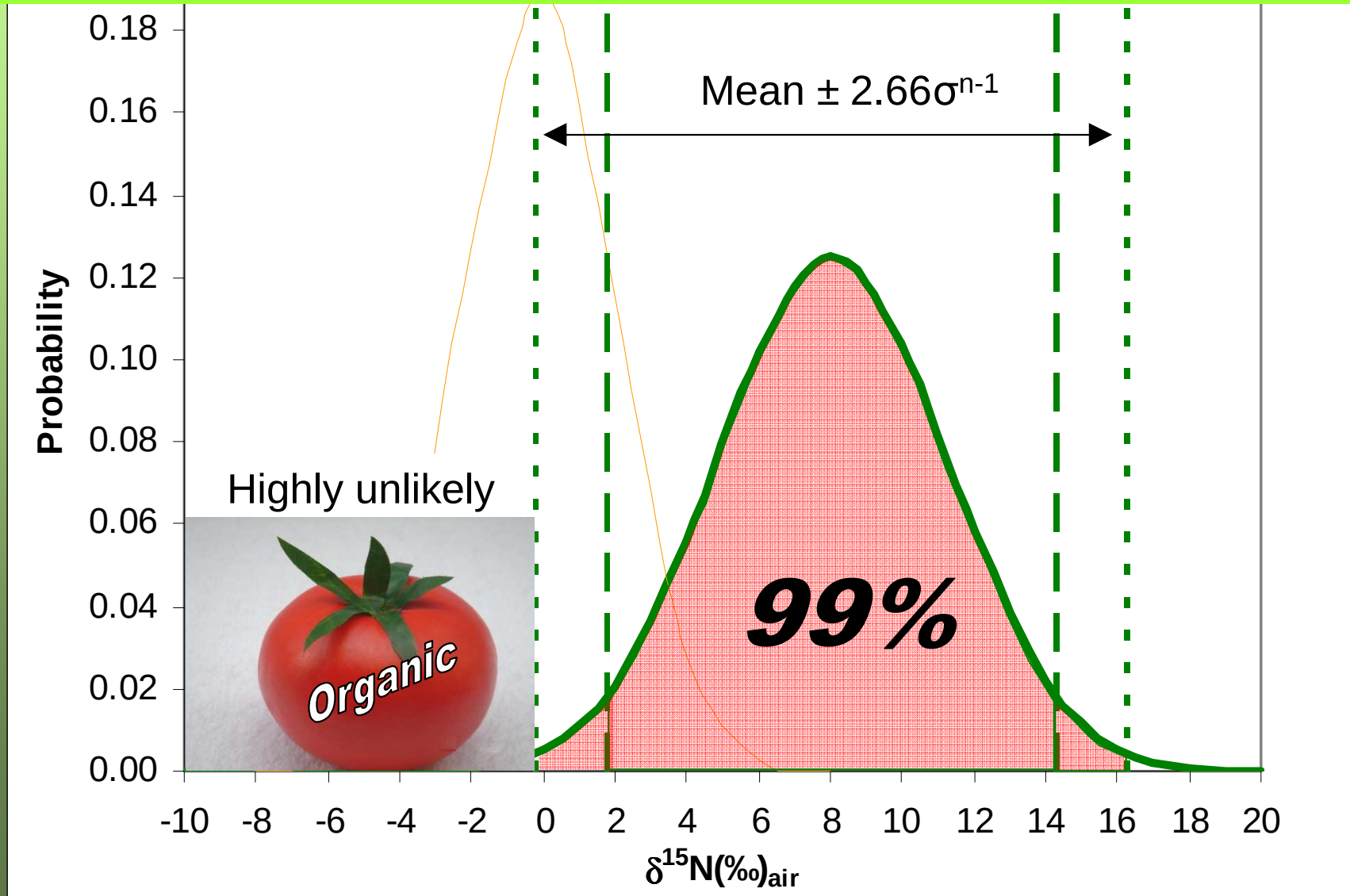

Organic
Conventional
Number of individuals
0
2
4
6
8
10
12
14
16
18
20
-6
-4
-2
0
2
4
6
8
10
12
14
16
18
δ 15N (‰)air

Tomatoes – normal dist^{n}

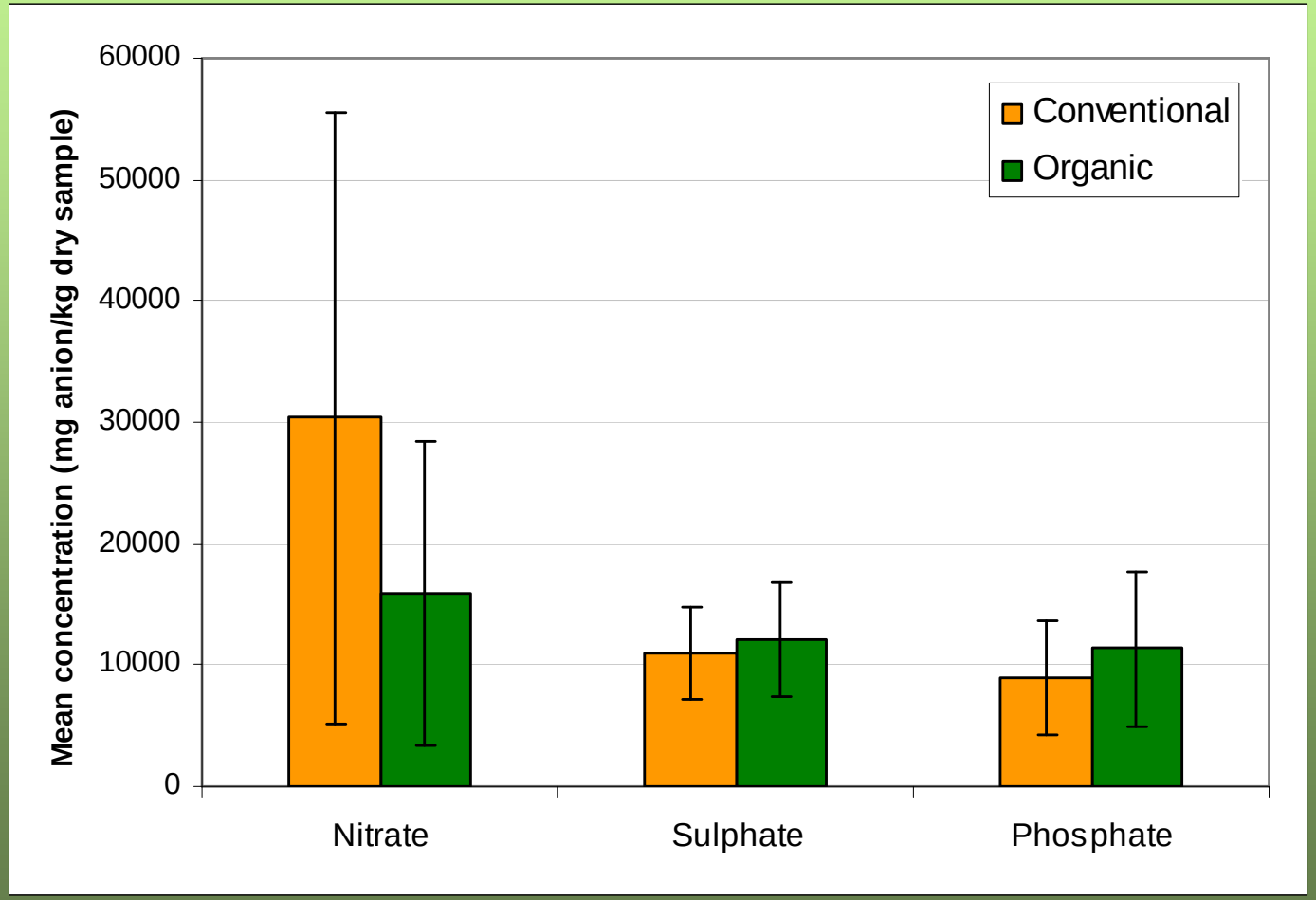



Probability
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Mean ± 2.0σ^n-1
Unlikely
Organic
95%
-10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20
δ15N(‰)air

A S Bateman, S D Kelly and M Woolfe (2007)
"Nitrogen isotope composition of organically and conventionally grown crops"
Journal of Agricultural and Food Chemistry , 55, 2664-2670.



Major anions – lettuces



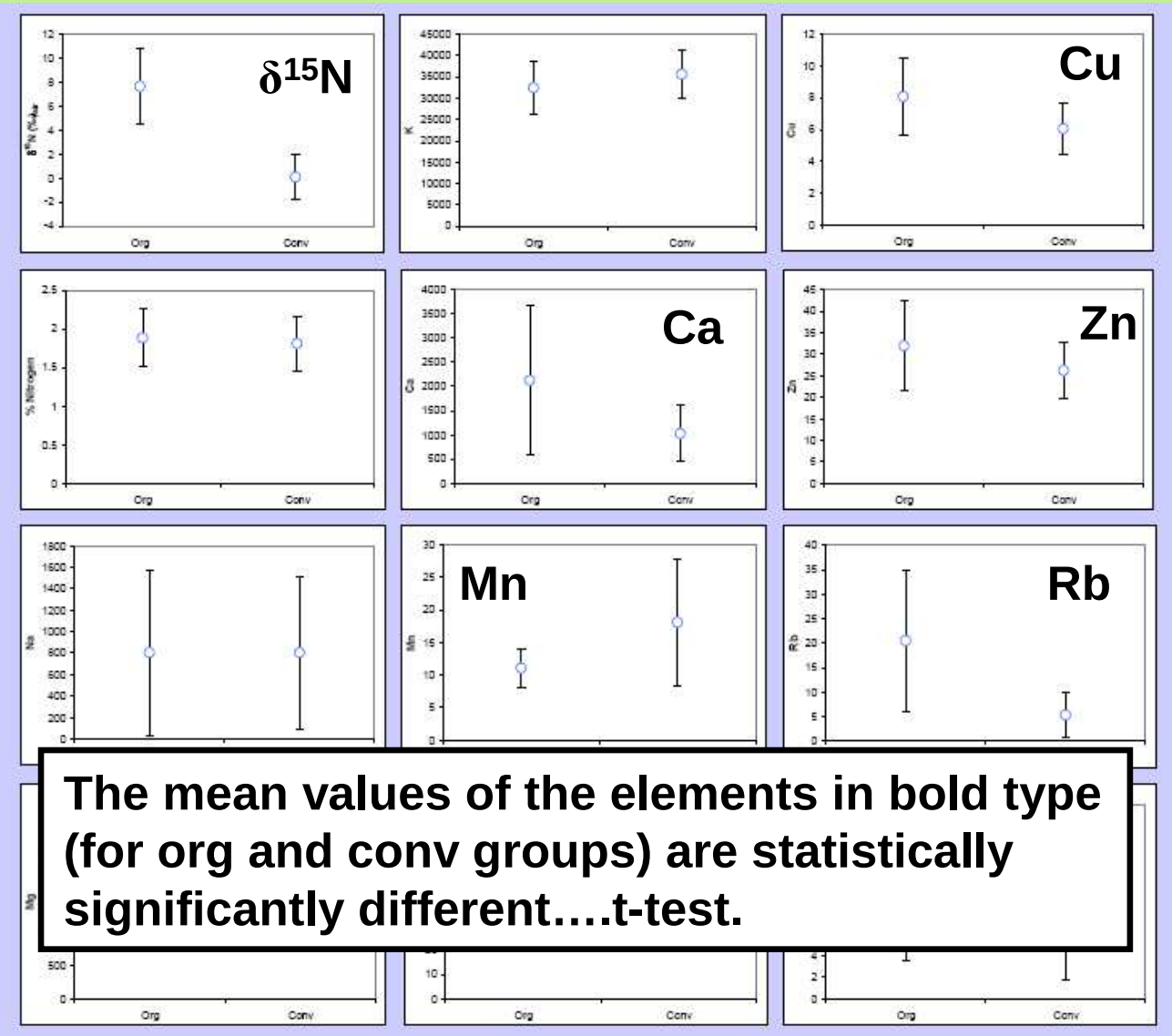
- May be related to water content, some evidence that excessive fertiliser application leads to rapid growth at least in part by swelling with more water (Siderer *et al*., 2005).

Conv, n=55
Org, n=48

Multi-element signatures

- Measure many elements simultaneously by ICP-MS (Na, Mg, K, Ca, Mn, Fe, Cu, Zn, Rb, Sr, Cd, Ba)
- Identify key variables that separate organic and conventional crops using Canonical Discriminant Analysis (CDA)
- We did not use an '*a priori*' hypothesis so if we see differences, we need to try and explain them.

Multi-element signatures (tomatoes)



The mean values of the elements in bold type (for org and conv groups) are statistically significantly different….t-test.

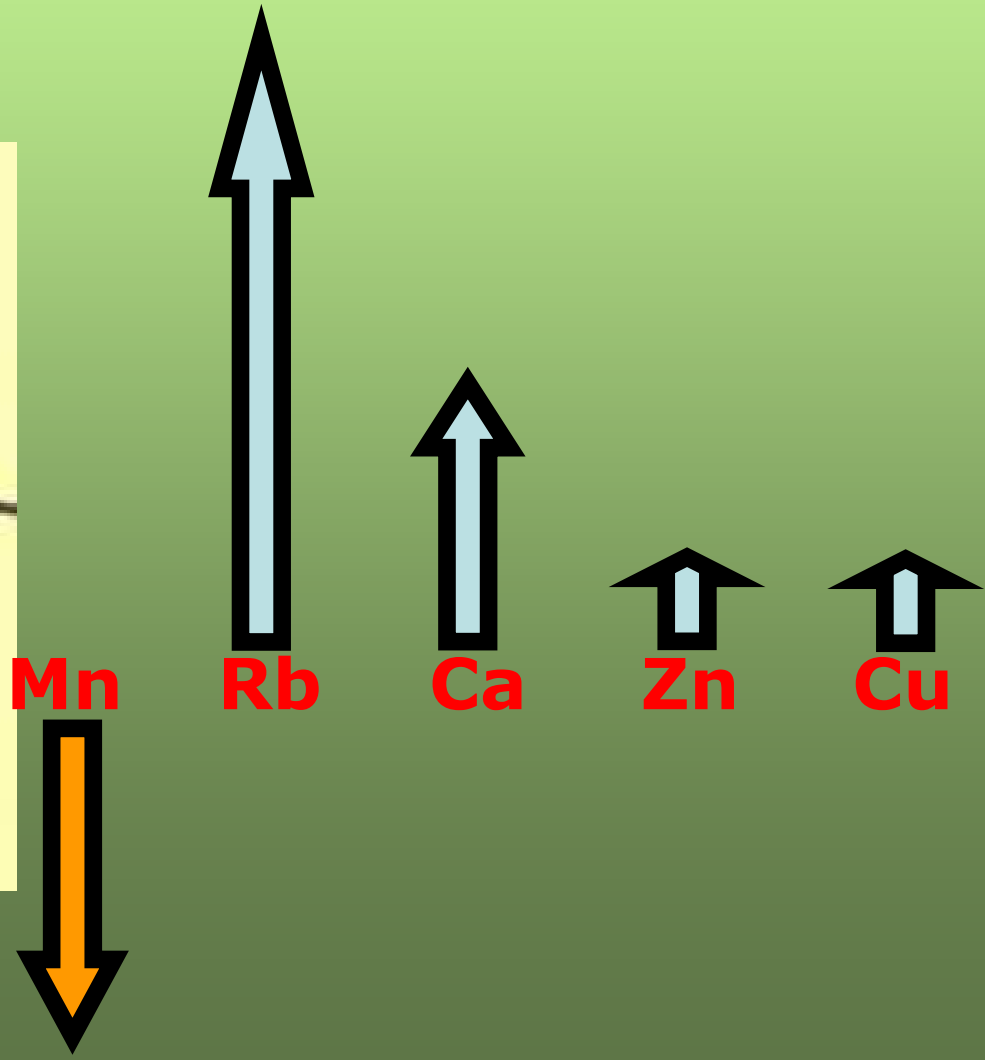
Ca	2x higher in org
Cu + Zn	slightly higher in org
Mn	2x lower in org
Rb	4x higher in org

Possible explanations

- Cu/Zn used in animal feed supplements, use of manure in org. cultivation?
- Rb usually geographical indicator. Soil grown vs hydroponic?
- More Mn available in hydroponic solution than naturally in soil?
- Mycorrhizal associations?

AMF – Arbuscular Mycorrhizal Fungi

(AMF Photo courtesy of the Agricultural Research Service Photo Unit.)



Canonical Discriminant Analysis (CDA)

- Looks at differences between two or more groups (org/conv) with respect to many variables (isotope + multi-element data).

- Identifies the variables that are best at placing an unknown sample into its appropriate group.

- Uses a linear combination of the multi-element & isotope data to maximise the separation between the groups.

CDA Results

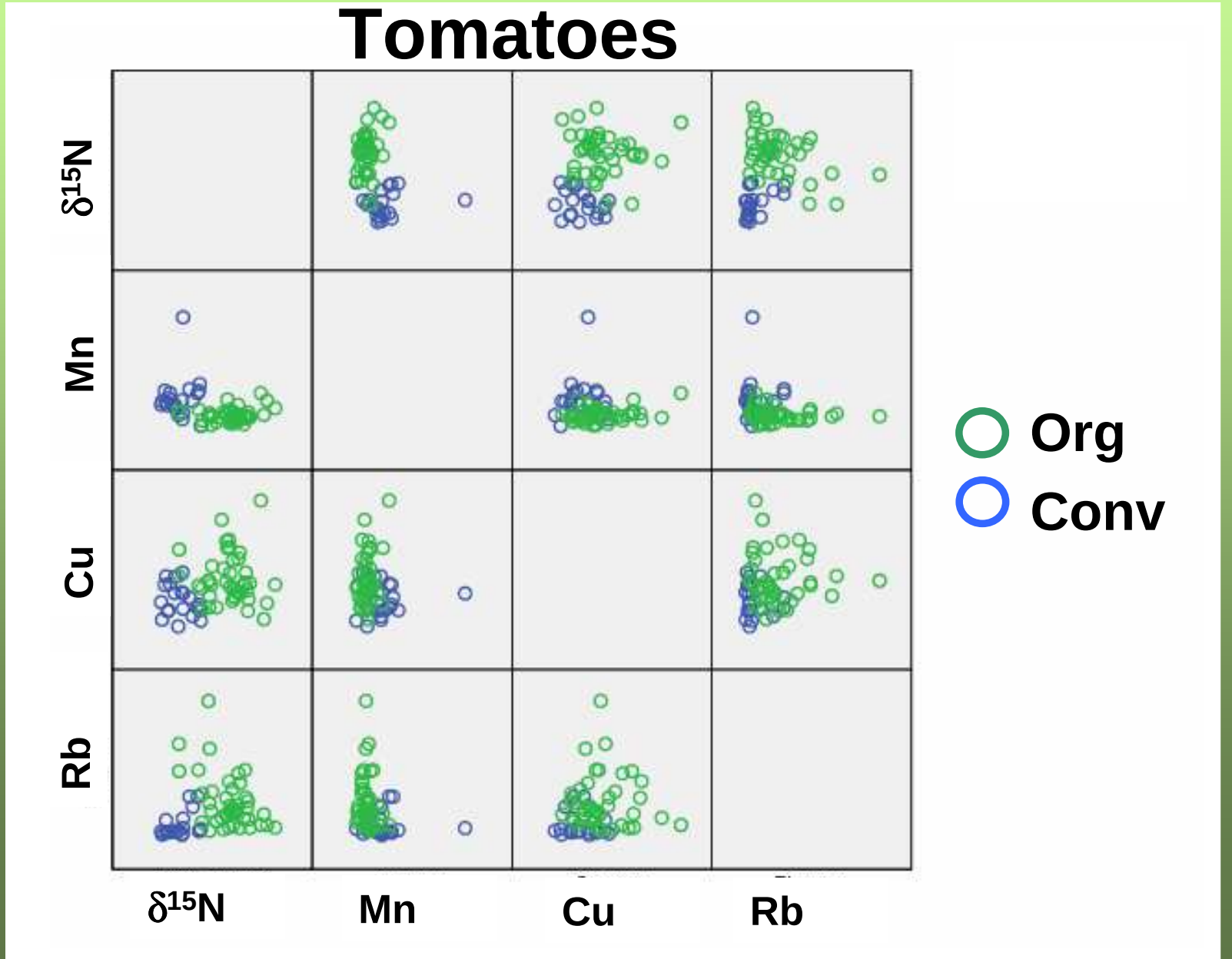
i) Tomatoes

	Variables entered	Predictor variables	Number of individuals	Conventional		Organic		Overall
Year 1	$\delta^{15}N$, %N	$\delta^{15}N$	51	18/18	100%	30/33	90.9%	94.1%
Year 1	$\delta^{15}N$, %N, multi-elements	$\delta^{15}N$, Rb, Cu, %N	51	18/18	100%	33/33	100%	100%
Year 1 + Year 2	$\delta^{15}N$, %N	$\delta^{15}N$	107	45/46	97.8%	57/61	97.8%	95.3%

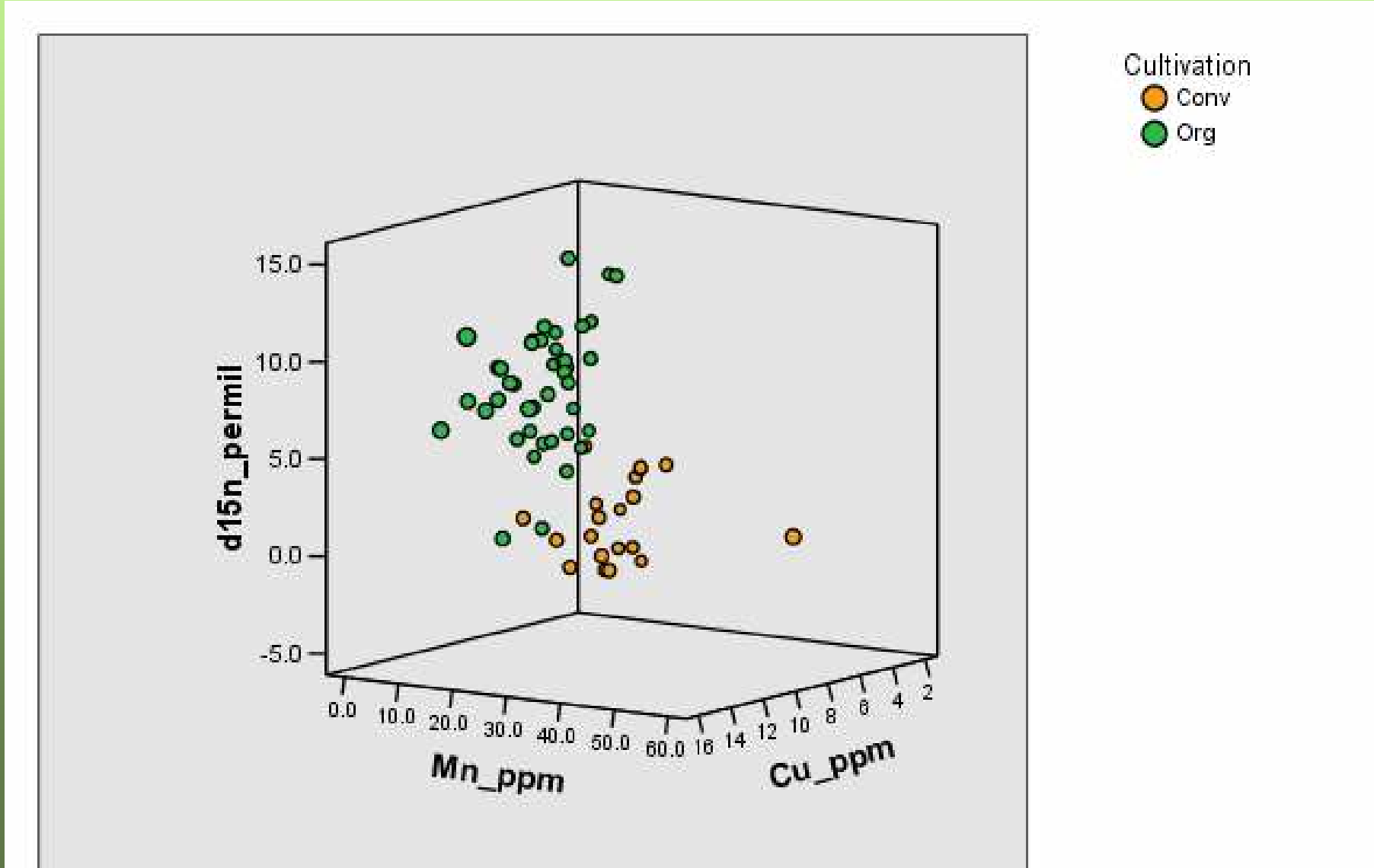
ii) Lettuces

	Variables entered	Predictor variables	Number of individuals	Conventional		Organic		Overall
Year 1	$\delta^{15}N$, %N	$\delta^{15}N$	42	21/28	75%	10/14	71.4%	73.8%
Year 1	$\delta^{15}N$, %N, NO_3, SO_4, PO_4	NO_3, SO_4, PO_4	42	22/28	78.6%	10/14	71.4%	76.2%
Year 1	$\delta^{15}N$, %N, NO_3, SO_4, PO_4, multielement data	Rb, $\delta^{15}N$	42	24/28	85.7%	8/14	57.1%	76.2%
Year 1 + Year 2	$\delta^{15}N$, %N	$\delta^{15}N$	103	46/55	83.6%	30/48	62.5%	73.8%
Year 1 + Year 2	$\delta^{15}N$, %N, NO_3, SO_4, PO_4	$\delta^{15}N$, %N, NO_3, SO_4	103	45/55	81.8%	34/48	70.8%	76.7%

arbuscular mycorrhizal fungi (AMF) ?



Tomato Data - 3-D Scatter Plot for variables $\delta^{15}N‰$, Mn (ppm), Cu (ppm) & Rb (ppm)



Conclusions

1. ^{15}N analysis is not definitive but may provide evidence to corroborate whether chemical N fertiliser has been applied to a crop.
2. Methodology is more suitable for some crop types than others e.g. hydroponic conventional versus Organic soil grown tomatoes, peppers..
3. Multi-element analysis improves classification rates from 95% to 100% for tomatoes.
4. Differing concentrations of Mn, Cu and Rb may be attributable to AMF

Other work – Patent application

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(WO/2003/087813) METHOD FOR DISCRIMINATING ORGANIC AGRICULTURAL PRODUCTS FROM CONVENTIONAL AGRICULTURAL PRODUCTS BY USING NITROGEN ISOTOPE INDEX

Biblio. Data | Description | Claims | National Phase | Notices | Documents

Latest bibliographic data on file with the International Bureau

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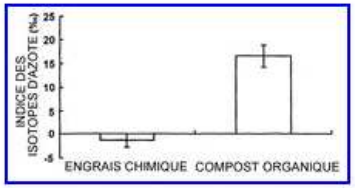
CHOI, Woo-Jung [KR/KR]; 408-906 Wooman Jugong Apt., 300, Wooman-dong, Paldal-gu, Suwon-city, Kyonggi-do 442-191 (KR).

Agent: **LEE, Young-Pil**; The Cheonghwa Building, 1571-18, Seocho-dong Seocho-gu, Seoul 137-874 (KR).

Priority Data: 10-2002-0019956 12.04.2002 KR

Title: METHOD FOR DISCRIMINATING ORGANIC AGRICULTURAL PRODUCTS FROM CONVENTIONAL AGRICULTURAL PRODUCTS BY USING NITROGEN ISOTOPE INDEX

Abstract: The present invention provides a method for discriminating an organic farmland from a conventional farmland, comprising; (a) measuring an amount of nitrogen isotope in a soil sample of a farmland; (b) calculating a nitrogen isotope index according to the formula (I) using the resultant nitrogen isotope value and (c) determining whether the farmland belongs to an organic farmland or a conventional farmland. According to the present invention, it is possible to objectively discriminate an



Patents applied for in…

Europe

United States

Mexico

China

Canada

Australia

Other work

Accred Qual Assur (2002) 7:378–387
DOI 10.1007/s00769-002-0531-6

GENERAL PAPER

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19

THE USE OF NITROGEN ISOTOPIC ANALYSIS TO DISTINGUISH BETWEEN ORGANIC AND CONVENTIONAL PRODUCTS

Eric Jamin*, Stéphanie Lescuyer, Delphine Salvat-Brunaud, Michèle Lees

Eurofins Scientific Analytics, Nantes, France *Corresponding author e-mail : EricJamin@Eurofins.com

Application of Nitrogen Stable Isotope Ratio as an Indicator for Organic Fertilized Vegetable

Akimasa NAKANO and Yoichi UEHARA

Bulletin of the National Institute of Vegetable Tea Science, 3, 119-128

JESIUM 2004 **A Stable Future**
Posters

Isotope characteristics of vegetables and wheat from conventional and organic production

idt, Andreas Rossman, Susanne
rmann Schnitzler, Michael Georgi,
Gerhard Zimmermann and Ralf
Winkler

JESIUM, 2004, Vienna A Stable Future

Organic vegetables: Authentication using stable isotopes

Rogers, Karyn

Rafter Isotope Laboratory, Geological
31-312, Lower Hutt, New Zealand, I

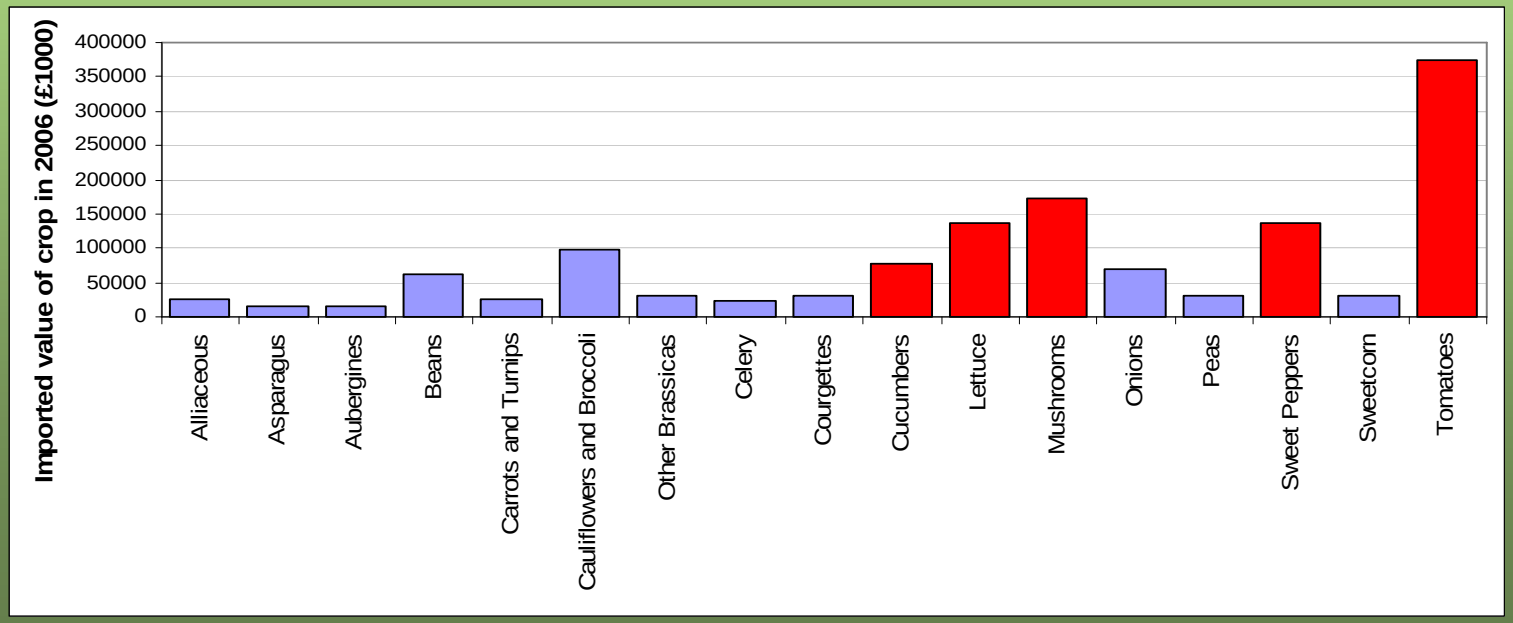
SHORT COMMUNICATIONS
Published in J. Environ. Qual. 37:182–185 (2008).
doi:10.2134/jeq2007.0329

Isotopic Discrimination as a Tool for Organic Farming Certification in Sweet Pepper

Francisco M. del Amor* **and Joaquín Navarro** Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario
Pedro M. Aparicio UPNA CSIC

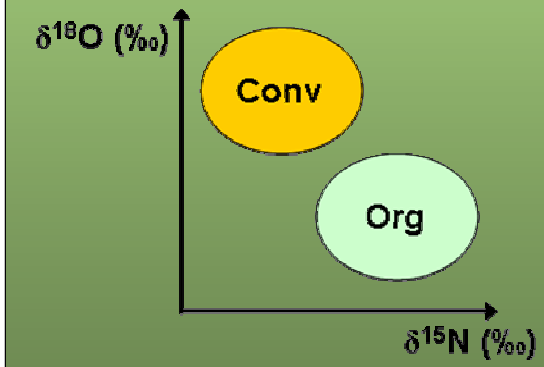
Future Work - we would like to…

- Extend the existing databases to include more EU (non-UK) and worldwide samples
- Target other high value horticultural crops and extend databases to see if exploitable differences in the $\delta^{15}N$ of org/conv crops exist, e.g. sweet pepper and cucumbers.
- Analyse the $\delta^{18}O$ of extracted nitrate from organic/conventional crops to see if differences exist
- Examine the applicability of secondary metabolite profiling (metabolomics)



DEFRA, Basic Horticultural Statistics, (2007)
http://statistics.defra.gov.uk/esg/natstat.asp

Dual isotope approach



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for TE measurements

For funding this research

Thank you for your attention!

Simon.Kelly@bbsrc.ac.uk