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Stress in Plants: some perspectives on the effects on the biochemical and physiological parameters

Inaugural Lecture :Prof David Mxolisi Modise

16th August 2019

Definition: Stress

Frustration, unhappiness and emotional strain or tension adverse or demanding circumstances

- Plants stress can be imposed by environmental conditions –El Nino

- Abiotic stresses – develop technologies & strategies to ameliorate damage to plants by stress

Fascination with Stress

Environmental conditions at Oudtshoorn, Western Cape & Botswana.

.

Presentation Protocol

- Part 1- Water stress imposition on Festuca, Peach and Strawberry
- Part 2 – Indigenous crops growing under water deficit conditions
- Part 3 - Climate change and crop response to drought
- Part 4 - Acid Mine Drainage as a stress factor and potential for Agriculture

PART 1: Water stress imposition of Festuca, Peach & Strawberry

TR 1 = Sodic water

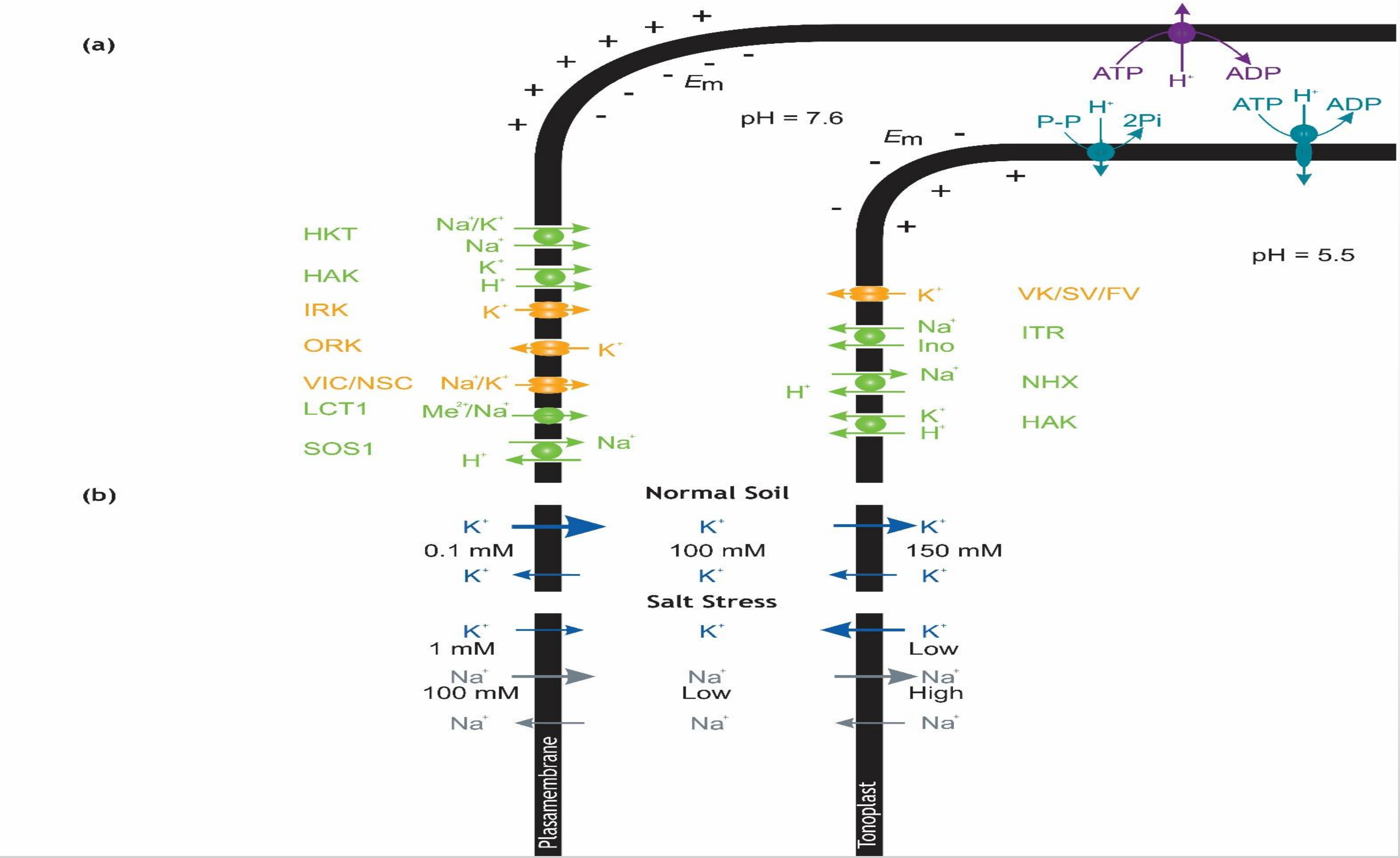
TR 2 = Drought and Sodic water

TR 3 = Drought

TR 4 = Normal

Treatments and Major Findings

- Drought treatments - withholding water over 2 days
- Normal water regime was *ad lib* irrigation to field capacity
- Plants in TR 1 performed better



(a)
Em
pH = 7.6
ATP
H+
ADP
P-P
2Pi
Em
pH = 5.5
HKT
Na+/K+
Na+
HAK
K+
H+
IRK
K+
ORK
K+
VIC/NSC
Na+/K+
LCT1
Me2+/Na+
SOS1
Na+
H+
K+
VK/SV/FV
Na+
Ino
ITR
Na+
H+
NHX
K+
H+
HAK
(b)
Normal Soil
K+
0.1 mM
K+
K+
100 mM
K+
K+
150 mM
K+
Salt Stress
K+
1 mM
Na+
100 mM
Na+
K+
Na+
Low
Na+
K+
Low
Na+
High
Na+
Plasamembrane
Tonoplast

West Virginia University

- A concept of using split roots Weaver *et al* (1922), Hunter & Kelly (1946) Kirkham (1983), Simonneau and Habit (1994)

- Caldwell and Richards (1989)

- ‘Hydraulic lift’(HL) - peach trees with split roots used


Dry pot
Grafted shoot
Split root
Tensiometer

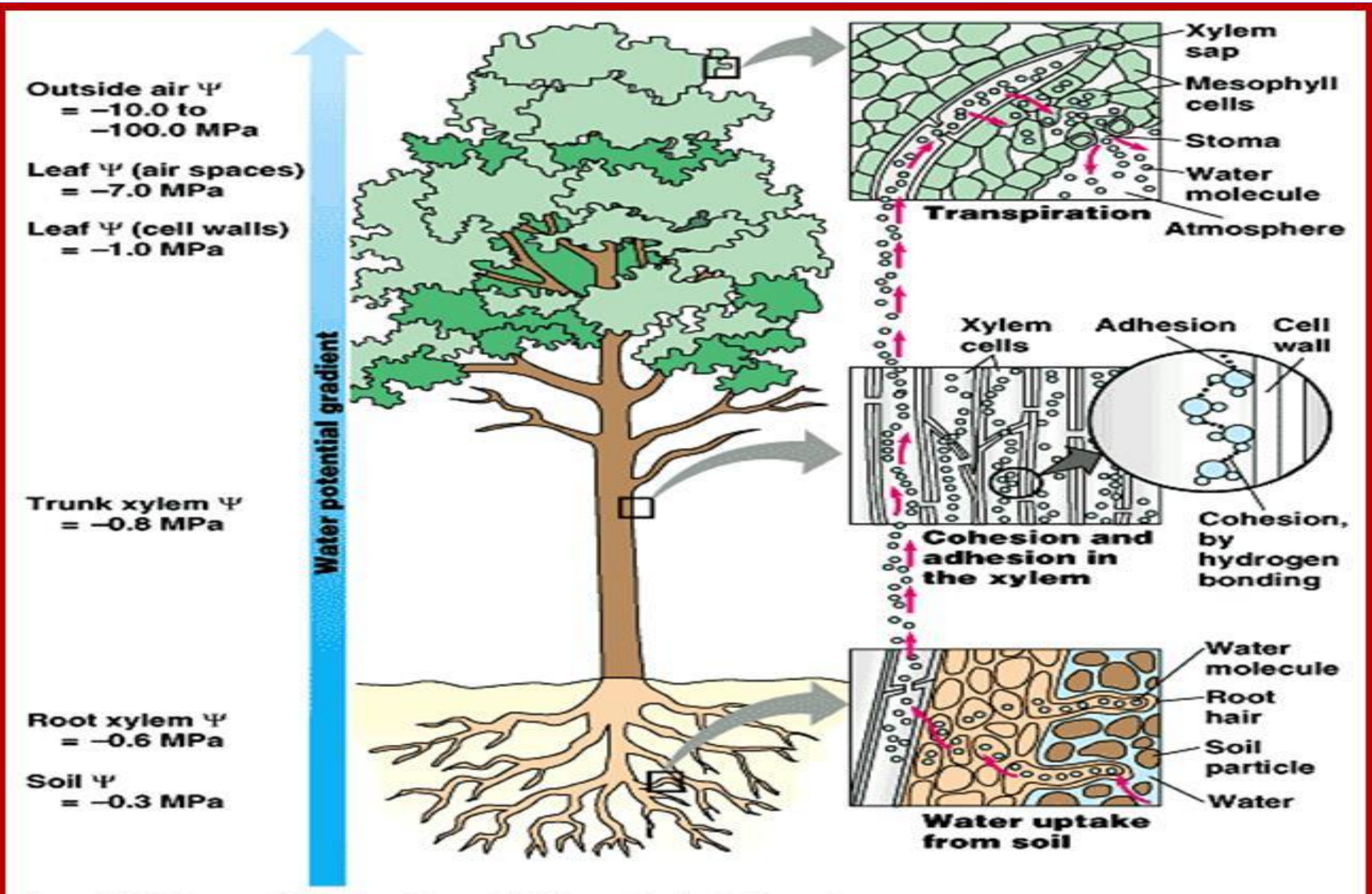
Procedure

- **Water potential gradients measured - Scholander Pressure Bomb**
- **First procedure of the kind - direct Ψw in roots**
- **Ψw = ΨS + ΨP** 0 to -7 Mpa

Findings continued

- Water movement into the roots from the soil - Ψs in roots
- Roots increases Ψp water and movement to apex
- Water, cohesion and hydrogen bonding in water
- Water movement from wet to dry pots of high tension - HL Evidence of ^{15}N isotope

The transpiration pull



Nottingham University

Effects of water stress on organoleptic quality of strawberry *(Fragaria ananassa L)*

Water stress treatments on phenological stages

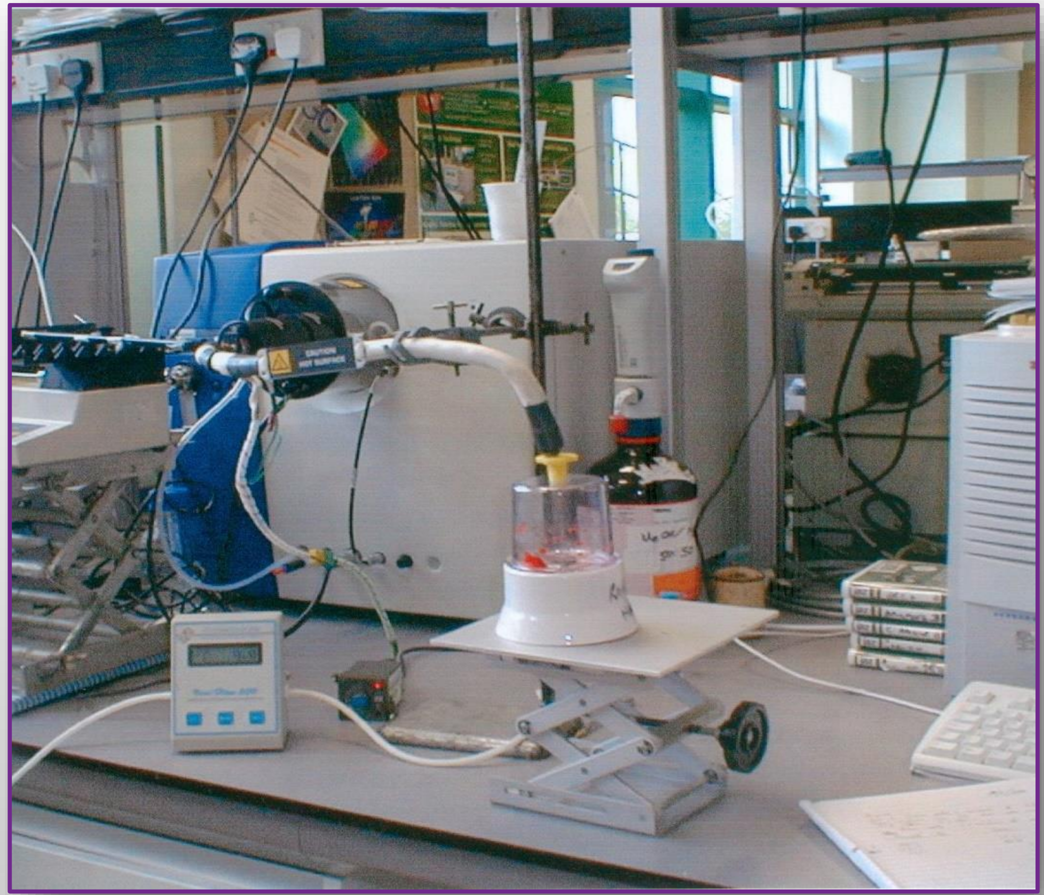
Water stress at flowering

Water stress at fruiting

Plate Water stress at maturing stage

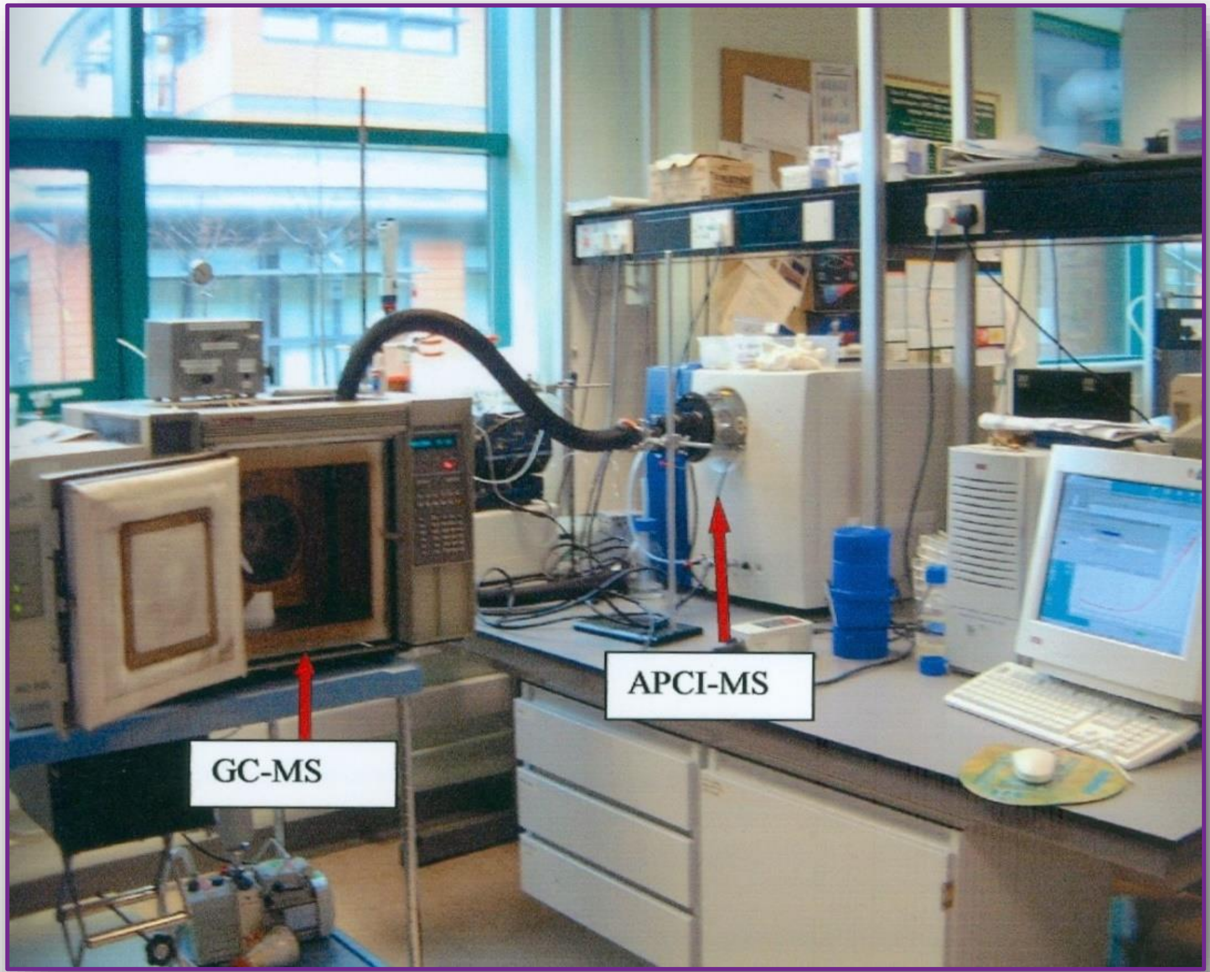
Comparison of APCI-MS and GC-MS in measuring of organic volatile compounds (OVC's)

Due to perishability of strawberry fruits this study determined best OVC method



The Atmospheric Pressure Chemical Ionisation (APCI) – Mass Spectrometer (MS)

(Food Science Laboratory – University of Nottingham).



Atmospheric Pressure Chemical Ionisation (APCI-MS) VERSUS Gas Chromatograph-Mass Spectrometer (GC-MS)

South African Journal of Botany 2004, 70(2): 306–309

SOUTH AFRICAN JOURNAL OF BOTANY
ISSN 0254–6299

Short Communication

Flavour volatile compound analysis in strawberry (*Fragaria* x *ananassa* Duch.) fruits: comparison of two mass spectrometer techniques for identifying volatile compounds

DM Modise[1*], CJ Wright[2], R Watson[2], R Linforth[2] and AJ Taylor[2]

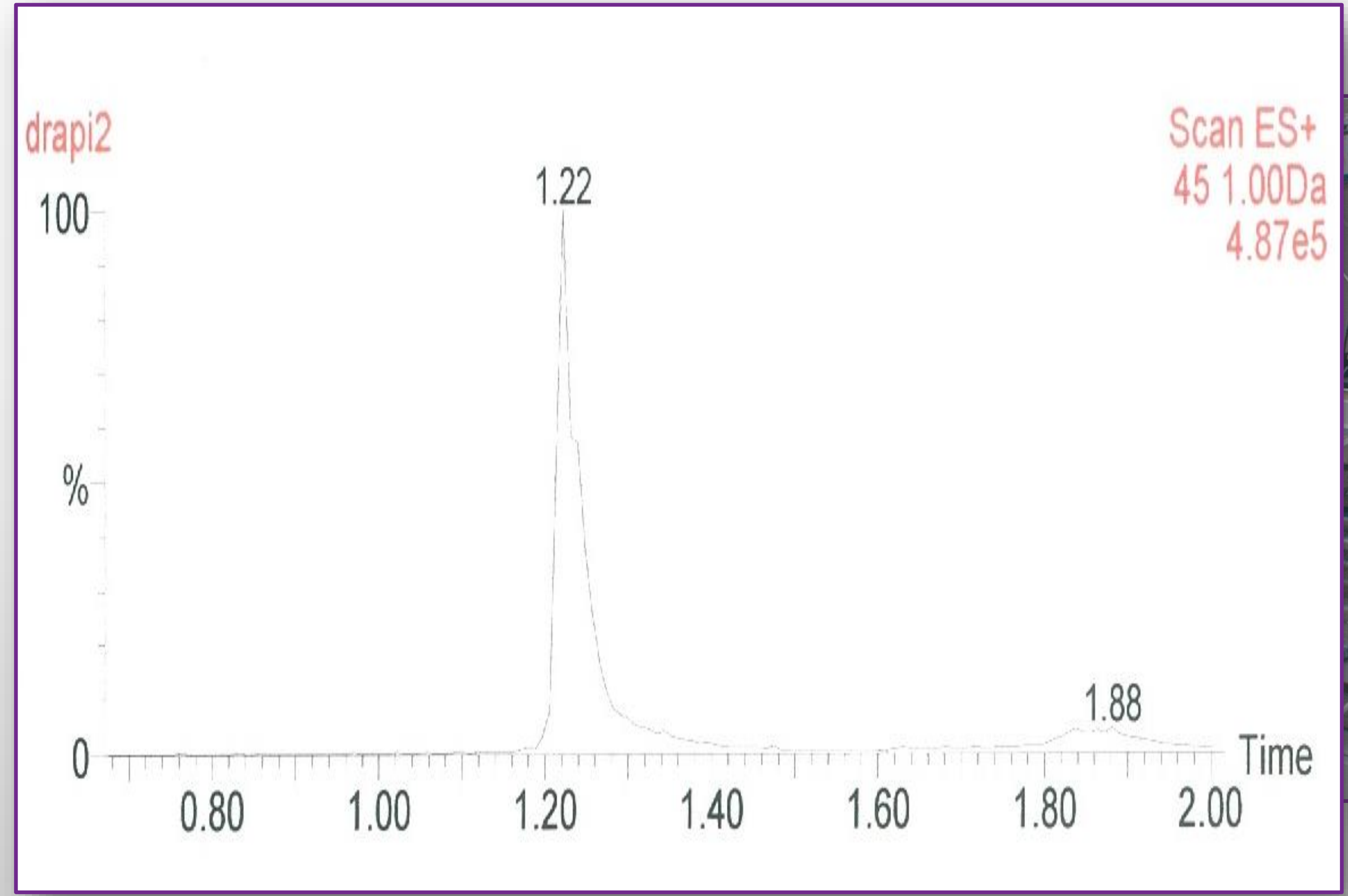
Findings

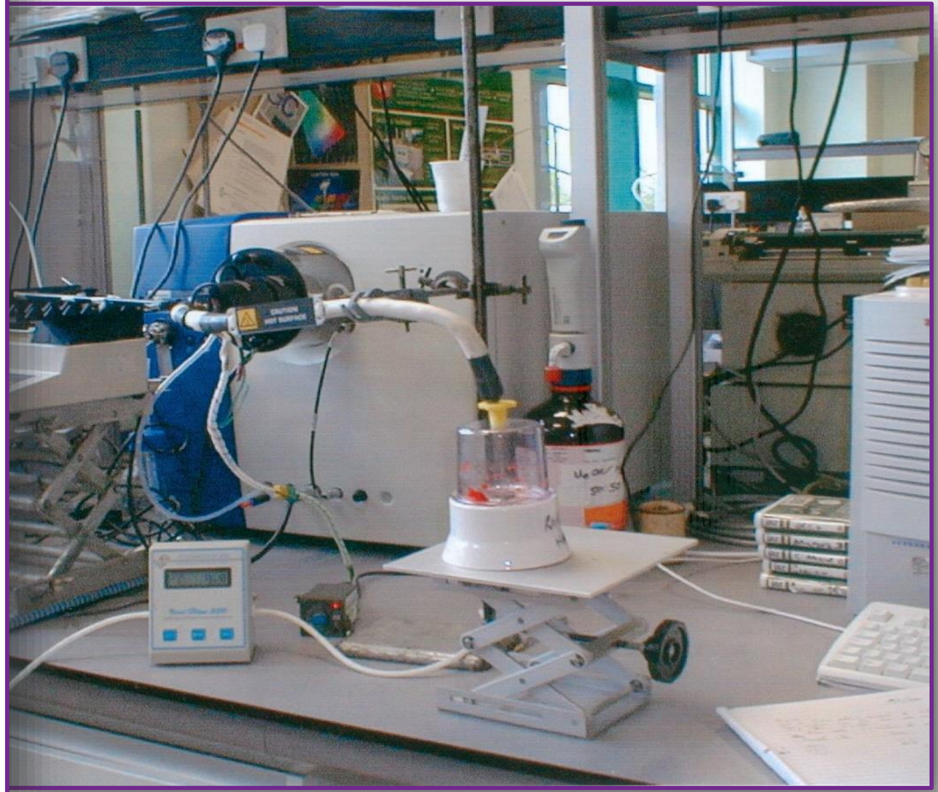
- Good agreement on the compound identity
- GC–MS gave a different identity to 5 OVC’s
- The APCI–MS vs GC MS

Identification of OVC’s by APCI-MS & GC-MS

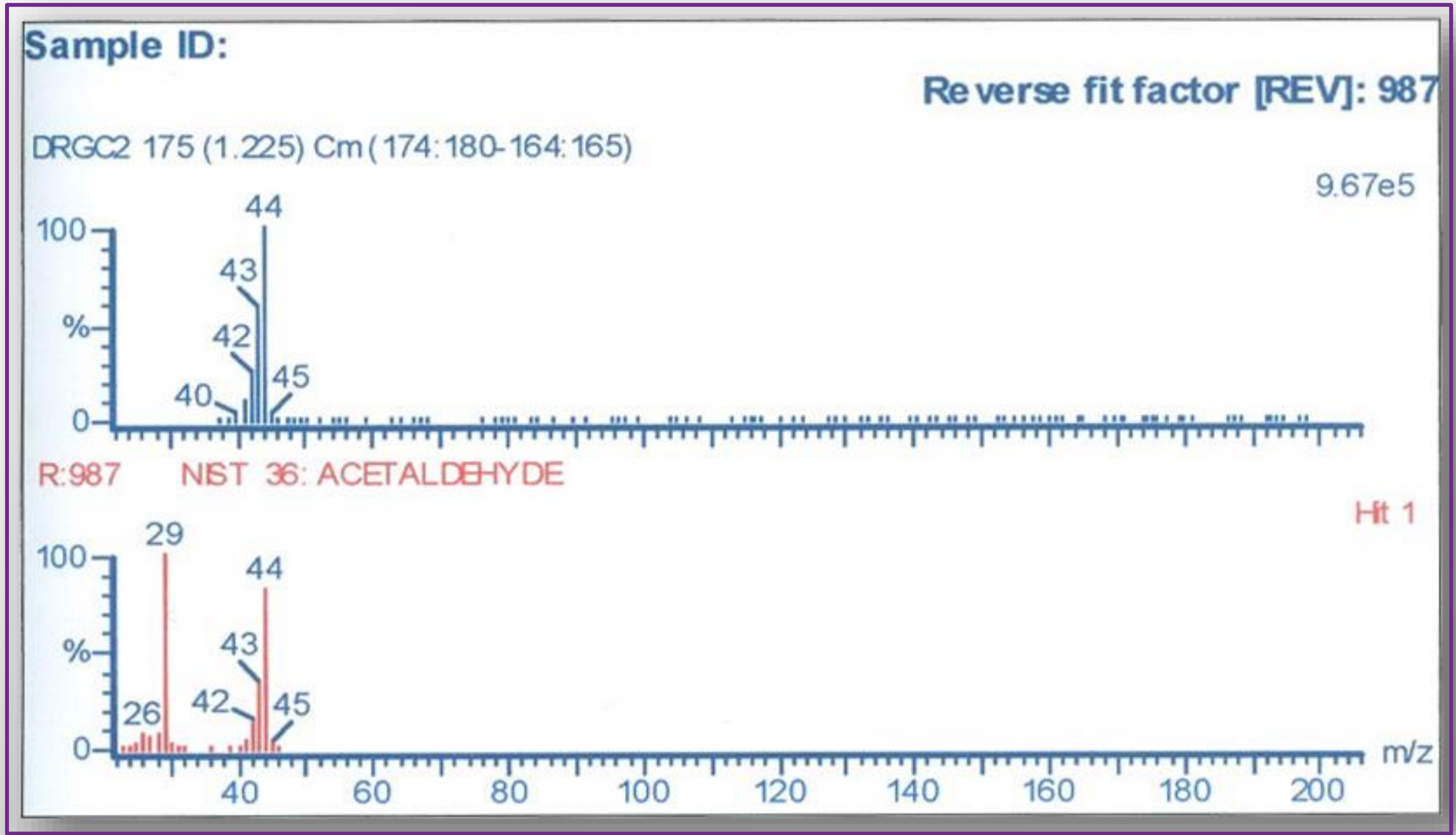
Ion mass	Probable compound	Actual identity after validation by GC-MS
45.3	Acetaldehyde	Acetaldehyde
59.2	Acetone	Acetone
61.2	Acetic acid	Ethyl acetate
75.2	Methyl acetate	Methyl acetate
89.3	Ethyl acetate	Ethyl acetate
99.3	(E)-Hexenal	3-Hexenal (Z)
101.2	Hexanal	Hexanal
103.2	Methyl butyrate	Methyl butyrate
115.2	Heptanone	Methyl propyl acetate
117.2	Ethyl butyrate	Ethyl butyrate
131.2	Ethyl methyl butyrate	Methyl hexanoate
143.2	Furanone	Hexyl acetate
145	Ethyl hexanoate	Methyl propyl butyrate
159.2	Ethyl methyl hexanoate	Ethyl methyl hexanoate

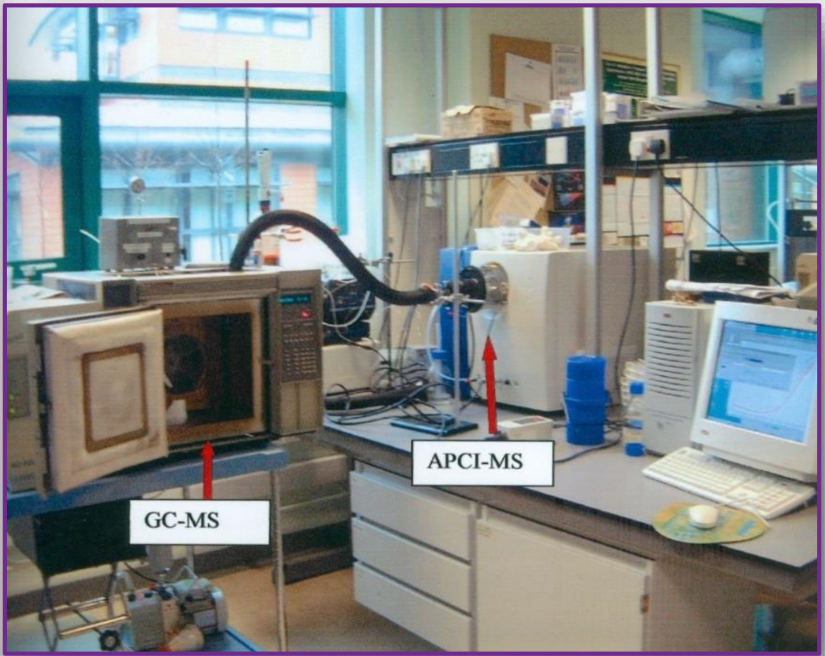
OVC by APCI e.g. acetaldehyde





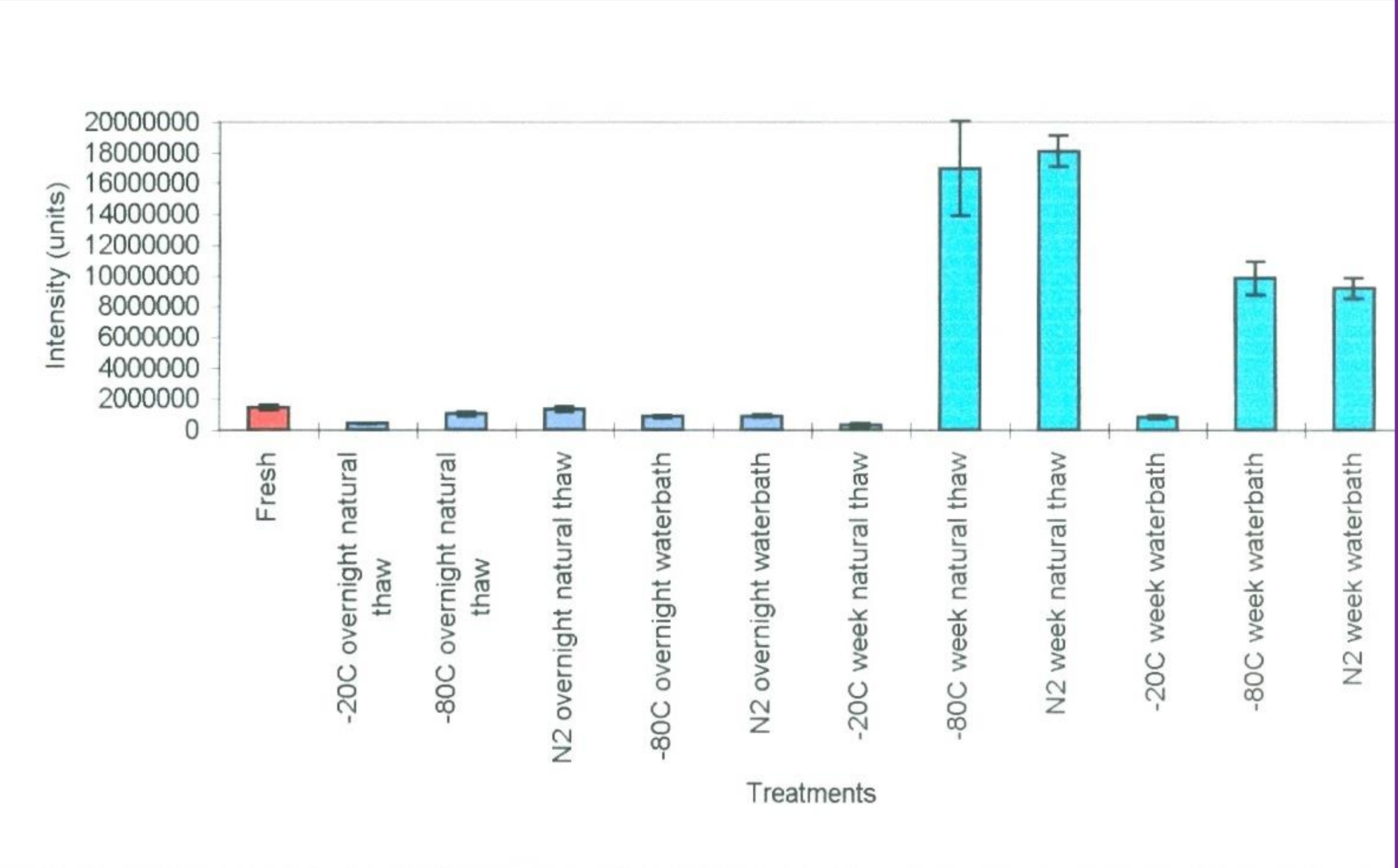
Confirmation of OVC by GC-MS





GC-MS library identification of compound with ion mass 45.1 m/z. GC-MS confirmed compound to be acetaldehyde, R = 98.7%

Freeze/Thaw Experiments



Intensity of 3-hexenal (Z)

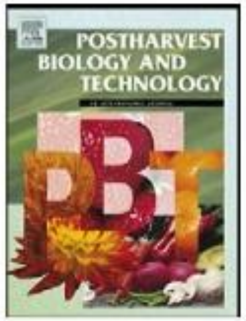
Freezing and thawing of strawberry fruits

Postharvest Biology and Technology 50 (2008) 25–30

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

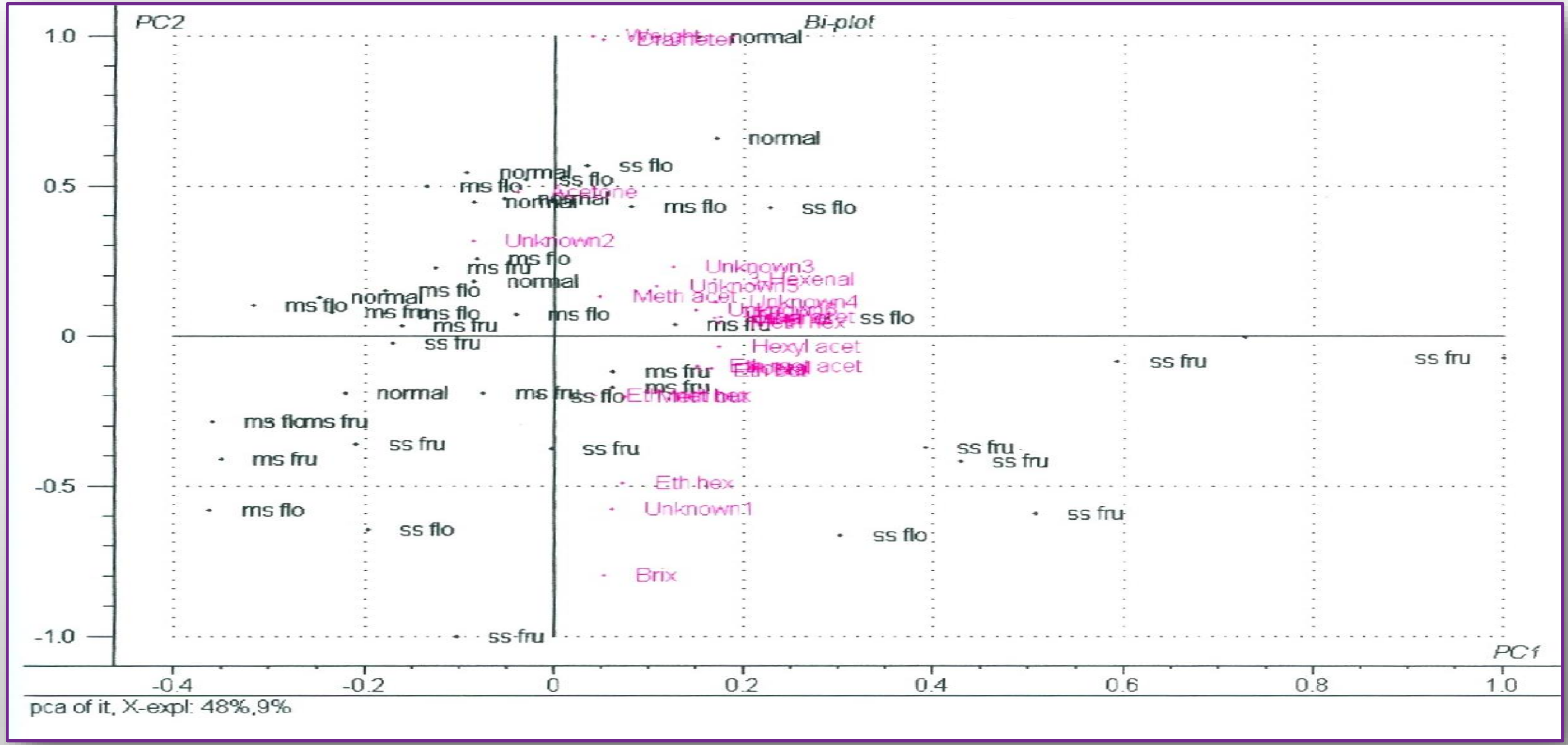


Does freezing and thawing affect the volatile profile of strawberry fruit (*Fragaria* × *ananassa* Duch.)?

D.M. Modise *

College of Agriculture and Environmental Sciences, University of South Africa (UNISA), P.O. Box 392, Pretoria 0003, South Africa

Principal Component Analysis



Principal component analysis bi-plot correlating water stress treatments to brix, weight, diameter of fruits and volatile compounds

Conclusions:

1. Festuca species under sodic stress treatment

2. ‘Hydraulic Lift’ existence demonstrated in peach under water stress

3. A technique for OVC analysis developed – applied internationally

4. Freezing and thawing can affect OVC abundance

5. Msfru provides best option for concentration of OVC’s

Part 2:
Indigenous crops growing under deficit water conditions

Desert Truffles
(*Kalaharituber pfeilii* Trappe)

Cracks in the soil indicative of presence of mature truffle fruiting body

The Nutritional and Economic Importance of the Kalahari Desert Truffles

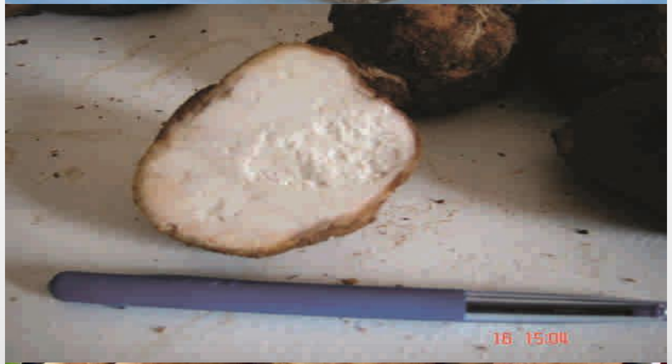
(*Kalaharituber pfeilii* Trappe)

Batches (g)	Zn	Cu	Fe	Na	K
40	28.11^{c}	28.45^{b}	364.41^{d}	113.62^{d}	1040.96^{a}
80	29.71^{c}	31.34^{b}	371.17^{d}	144.63^{c}	1039.00^{a}
120	34.18^{b}	39.06^{a}	398.58^{c}	162.12^{c}	1039.07^{a}
160	37.95^{a}	43.61^{a}	475.81^{b}	211.70^{b}	1039.72^{a}
200	38.59^{a}	43.85^{a}	492.32^{a}	269.81^{a}	1039.73^{a}

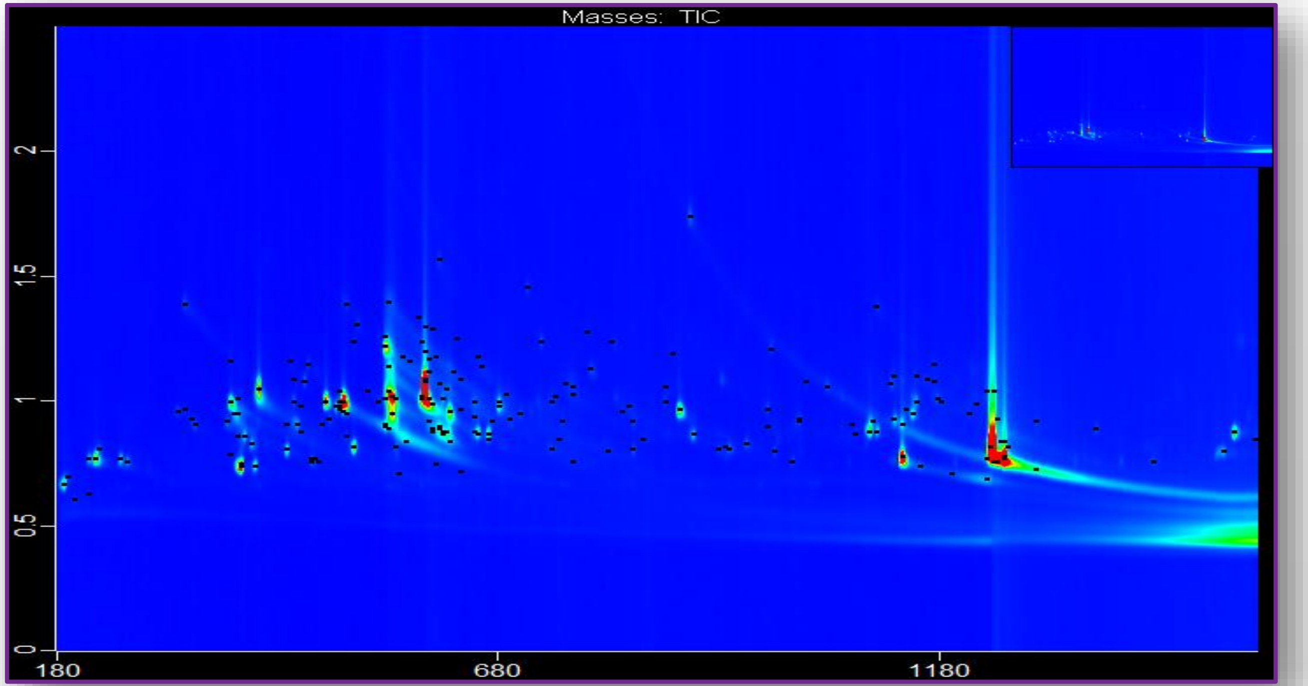
Mean within the a-column with the same letter are not significantly different

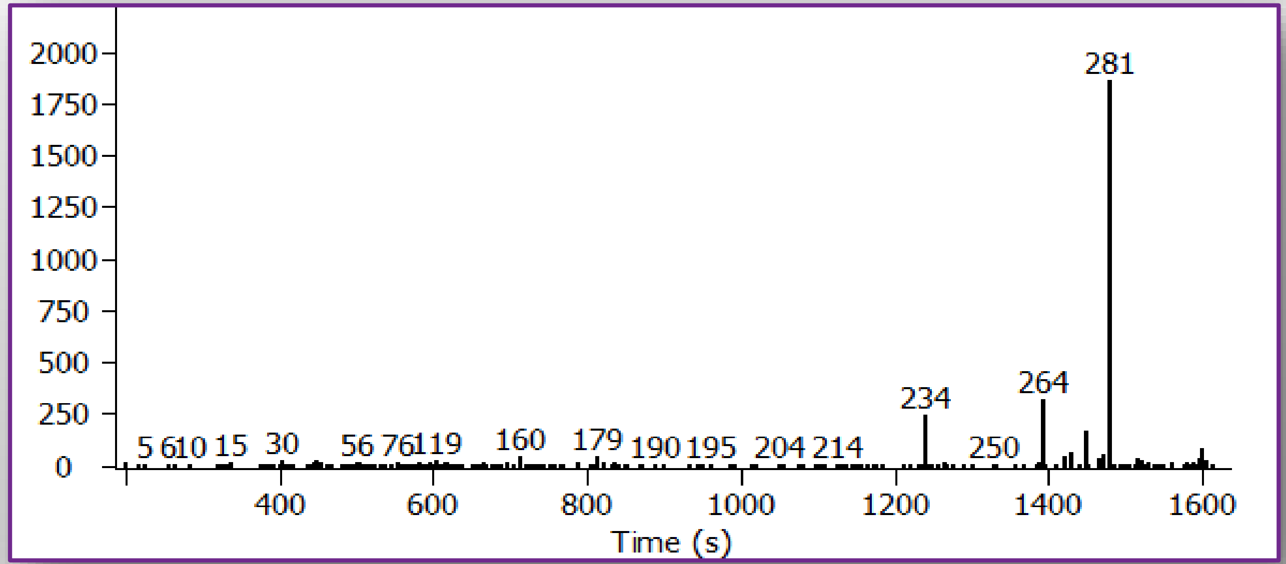
Mineral concentration in PPm (mg/litre)

Table 1 Mean mineral composition of Kalahari Truffles



Truffle ‘Bela’ Eotvas Lorand University, Budapest





Peter-Gorst Allman, David M Modise, Ben Burger *et al*

A 2 D Chromatogram of one of the truffle samples extracted using the Quechers method

Findings:

- The GCxGC-TOFMS coupled Quenchers is best than coupling with Soxhlet – first repor
- Over 200 compounds identified

UNISA university of south africa

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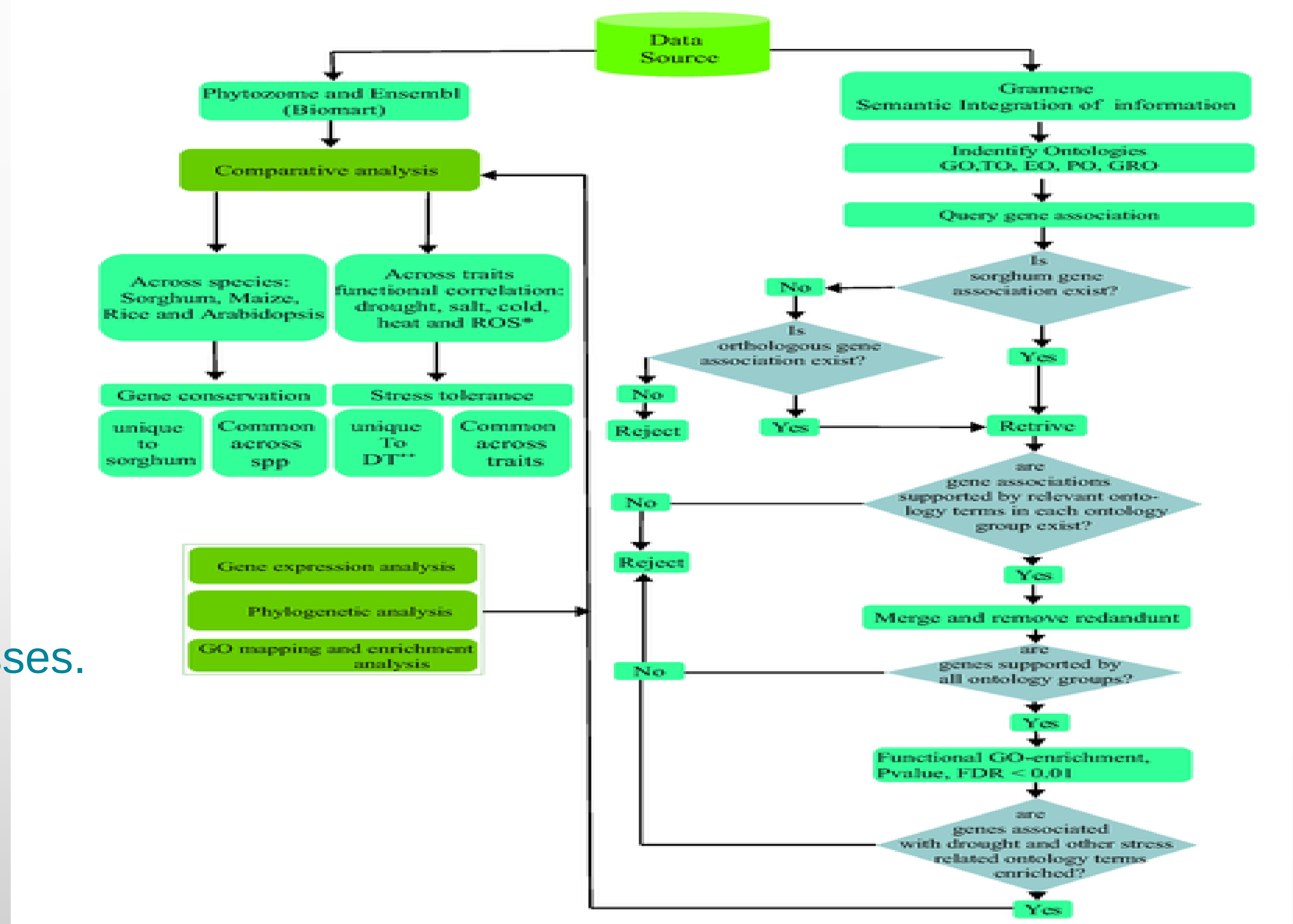
PART 3:
Climate Change & Crop Response to Drought

- **Response of crop plants to changing climate and global warming**

- **A component of my work with Dr Adugna *et al*. on the identification of genes in sorghum (*Sorghum bicolor* (L.) Moench**

Investigation of multiple stress response across species

Work-flow for gene-phenotype association across-species and stresses.



Methodology

- Five plant related ontologies, were identified using Gramene and Gene Ontology databases:

  - Gene ontology (GO)
  - Trait ontology (TO)
  - Plant ontology (PO)
  - Environmental ontology (EO)
  - Growth ontology (GRO)

Publication: PLOS ONE 13(3):

PLOS | ONE

RESEARCH ARTICLE

Cross-species multiple environmental stress responses: An integrated approach to identify candidate genes for multiple stress tolerance in sorghum (*Sorghum bicolor* (L.) Moench) and related model species

Adugna Abdi Woldesemayat[1,2]*, David M. Modise[3], Junaid Gemeildien[1], Bongani K. Ndimba[4,5], Alan Christoffels[1]

Findings

1. Plant genes linked to traits responding to stress combination across species identified
2. Common ancestral pool
3. Proximity of Sorghum to other 3 – association to drought
4. Info for comparative genomics

Other publications

Ind J Plant Physiol. (January–March 2018) 23(1):24–39
https://doi.org/10.1007/s40502-018-0357-9

ORIGINAL ARTICLE

Identification of proteins in response to terminal drought stress in sorghum (*Sorghum bicolor* (L.) Moench) using two-dimensional gel-electrophoresis and MALDI-TOF-TOF MS/MS

Adugna Abdi Woldesemayat[1,2,6] · David M. Modise[3] · Bongani K. Ndimba[4,5]

Received: 15 September 2017 / Accepted: 22 February 2018 / Published online: 21 March 2018

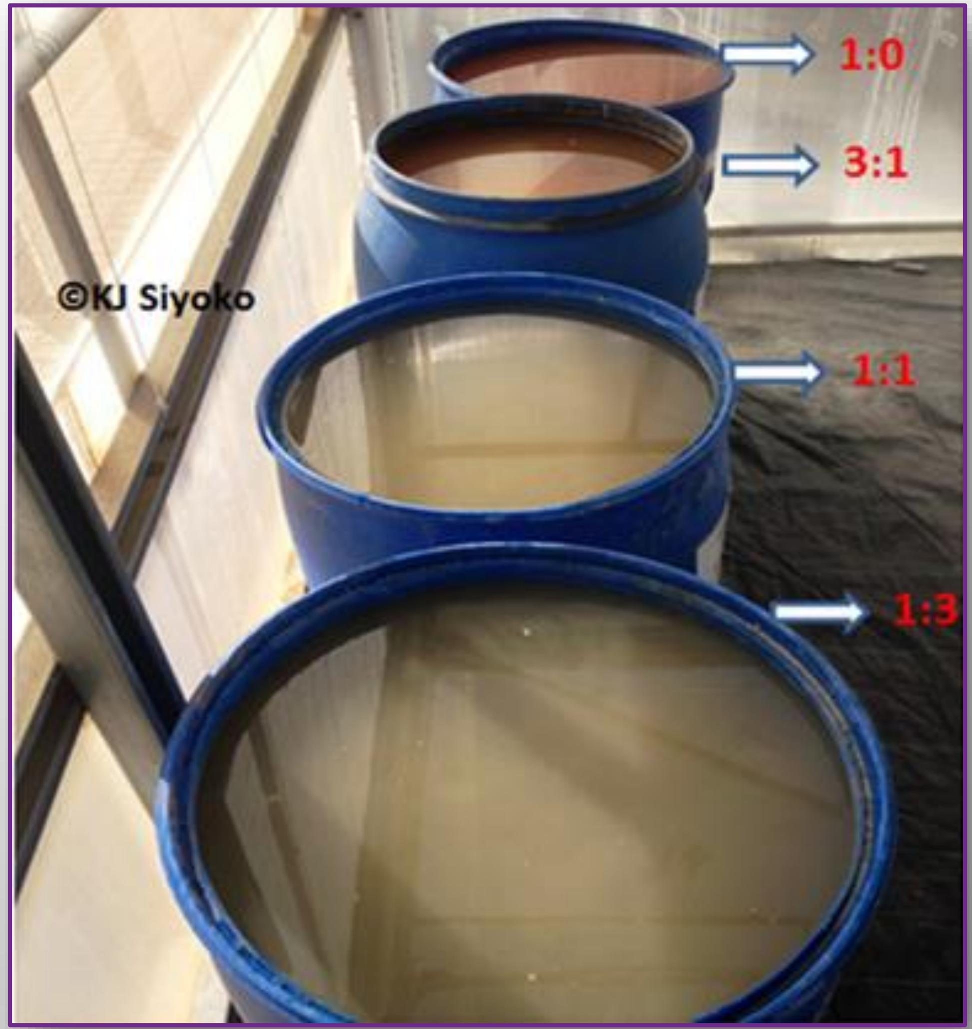
Findings

1.
2.

PART 4: Acid Mine Drainage(AMD)
As a Stress & Potential for Agriculture

AMD –mineral rocks oxidized & low pH

Use of fly ash to ameliorate AMD



Objective:

Evaluation the potential usefulness of AMD

Treatments:

- 100% (no FA) = 1:0
- 75% AMD (25% FA) = 3:1
- 50% AMD (50% FA) = 1:1
- 25% (75% FA) = 1:3

(Siyoko J, 2016)

Experimental plant material

a) Brassica oleracea var capitata

b) *Brassica oleracea* var acephala

c) *Solanum tuberosum* Solanacea

d) *Solanum tuberosum* (Solanacea)

Published in American Journal of Potato Research 2017

Am. J. Potato Res. (2017) 94:367–378
DOI 10.1007/s12230-017-9572-6

CrossMark

Assessment of Growth, Tuber Elemental Composition, Stomatal Conductance and Chlorophyll Content of Two Potato Cultivars Under Irrigation with Fly Ash-Treated Acid Mine Drainage

Maropeng Vellry Nemutanzhela[1] · David Mxolisi Modise[1] · Kotose Joseph Siyoko[1] · Sheku Alfred Kanu[1]

Major Findings

- 75% AMD growth and tuber yield
- Heavy metals Ni, Zn, and Sr found
- Reduced leaf stomatal conductance and chlorophyll content
- Cultivar response difference on - stomatal conductance, stem diameter, TSS, numbers of tubers, weight etc.

Metabolomic analyses

600 MHZ NMR

Other Publications

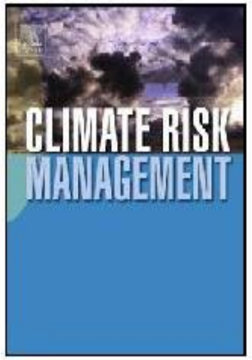
Climate Risk Management 16 (2017) 246–257

Contents lists available at ScienceDirect

Climate Risk Management

journal homepage: www.elsevier.com/locate/crm

ELSEVIER



Farmer's perception of climate change and responsive strategies in three selected provinces of South Africa

CrossMark

Zelda A. Elum [a,*], David M. Modise [a], Ana Marr [b]

[a] College of Agriculture and Environmental Sciences, University of South Africa, South Africa
[b] Natural Resources Institute, University of Greenwich, United Kingdom

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Overall Conclusions - Findings

- Stress studies – a lifetime work
- Significant contribution to the scientific world is notable in that:
  - Further understanding of the effects of stress on plants and crops
  - New techniques for measuring organoleptic properties of crops discovered
  - AMD water for use in the horticulture industry
  - Genes linked to stress traits in Graminae plant species identified
  - ***Potential for development of a prototype pump with Engineering for AMD***
  - Research outputs in good journals realized
  - Training of postgraduate students

CAUTIONARY NOTE: Disposal of AMD slurry

- Further work is underway to study water relations in the African horned cucumber (*Cucumis metuliferus* L.) and on potatoes looking at *metabolomics, genomic* and *proteomic* analysis of plant material under AMD, using fly ash and quick lime.

Other selected publications

- Maboloke A. Maatjie, Martin M Maboko and **David M Modise. 2018**. Yield of hydroponically grown tomatoes (Solanum lycopersicon) as affected by different particle sizes of sawdust. South African Journal of Plant and Soil. http://dx.doi.org/10.1080/02571862.2018.1424357

- Woldesemayat AA, **Modise DM** and Ndimba BK. **2017.** An integrated approach to identify candidate genes for multiple stress tolerance in sorghum (*Sorghum bicolor* (L.) Moench). Plos One 13 (3). DOI. 10.1371/journal.pone.0192678

- Nethononda PD, Nofemela R and **DM Modise**. **2017**. The bottom-up effects of cabbage cultivars on fitness of a larval parasitoid of *Plutella xylostella* (L.) (Lepidoptera: Plutellidae). African Entomology 25 (2): 302-310**.**

- Woldesemayat AA, Ntushelo K and **DM Modise**. **2017**. Identification and characterization of protein coding genes in Monsonia (*Monsonia burkeana* Planch. ex Harv) using a combination of approaches. Genes & Genomics 39: 245- 259.

- Elum ZA, Nhamo G and **DM Modise. 2017**. Climate change mitigation: The potential of agriculture as a renewable energy source in Nigeria. Environmental Science and Pollution Research 24: 3260-3273.

- Woldesemayat AA, Ntushelo K and **DM Modise**. **2016**. De novo sequence assembly of a partial transcriptome using leaf tissue in Monsonia (*Monsonia burkeana* Planch. Ex Harv). 3 Biotech 6 (2): 1-15.

- Nothononda PD, Nofemela R, MS and **DM Modise. 2016**. Development, survival, body weight and oviposition rates of *Plutella xylostella* (L.) (Lepidoptera*:* *Plutellidae*) when reared on seven cabbage cultivars. African Entomology 24 (1): 162-169.

- Bopape MJ, Rofemela, MS Mosiane and **DM Modise. 2014**. Effects of a selective and a broad-spectrum insecticide on parasitism rates of *Plutella*

- *xylostella* (L.) (*Lepidoptera: Plutellidae*) and species richness of its primary parasitoids. African Entomology 22(1): 115-126.

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Supervised Postgraduate Students and Postdoctoral Fellows

- **11 Master of Science students supervised to completion**

- **PhD's supervised to completion**

1. Dr Joseph Kotose Siyoko
2. Dr Mohammed Tufazzal
3. Dr Mike Leech

- **Current PhD students**

1. Mr Knox Maluleke
2. Ms Rabelani Munyai
3. Ms Maropeng Nemutanzhela
4. Ms Samukelisiwe Mdlalose
5. Mr Jaba Adugna – Ethiopia

- **Postdoctoral Fellows Supervised**

1. Dr Adugna Abdi Woldesemayat (Ethiopia)
2. Dr Zelda Elum (Nigeria)

Acknowledgements

- Late parents (biological and in-laws), family and friends – have promoted my academic journey in different ways
- Mr Peter Thoday – Academic Adviser at the University of Bath
- Dr Michael David Glen – USDA Fruit Research Laboratory (Academic Committee member MSc & mentor), USA
- Professor Morris Ingle (Late) – MSc supervisor, West Virginia University, USA
- Dr Charles Wright – PhD Supervisor (University of Nottingham)
- Dr Richard Watson – Postdoctoral Fellow and collaborator (University of Nottingham)
- Prof Alderton (Senior academics - University of Nottingham)
- Management of the College of Agriculture & Environmental Sciences (UNISA)
- Prof Linda Du Plessis (Deputy Vice Chancellor Operations and Vaal Campus) and Prof Refilwe Phaswana-Mafuya (Deputy Vice Chancellor of Research at NWU for their able leadership and infectious passion (all present today)
- Prof Eno Ebenso for his support and leadership in the faculty