Investigation of the mutagenicity of electromagnetic fields using the tradescantia micronucleus bioassay

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Motivation:

Clastogenic effects of radiofrequency radiations on chromosomes of tradescantia

Haider T, Knasmüller S, Kundi M, and Haider MJ

Mutation Research 1995, 324: 65-68.

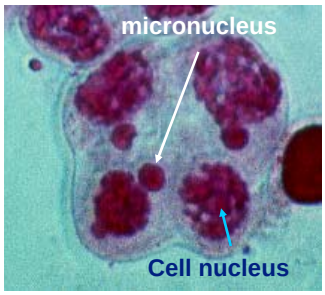
- Haider et al. showed - using the tradescantia bioassay - an increased micronuclei formation in plants exposed in situ near a short-wave radio transmitter.
- Mutagenic behaviour of EMF?

➢ "Replication" study in controlled laboratory environment

➢ Application to other frequencies and modulations

The tradescantia micronucleus bioassay:

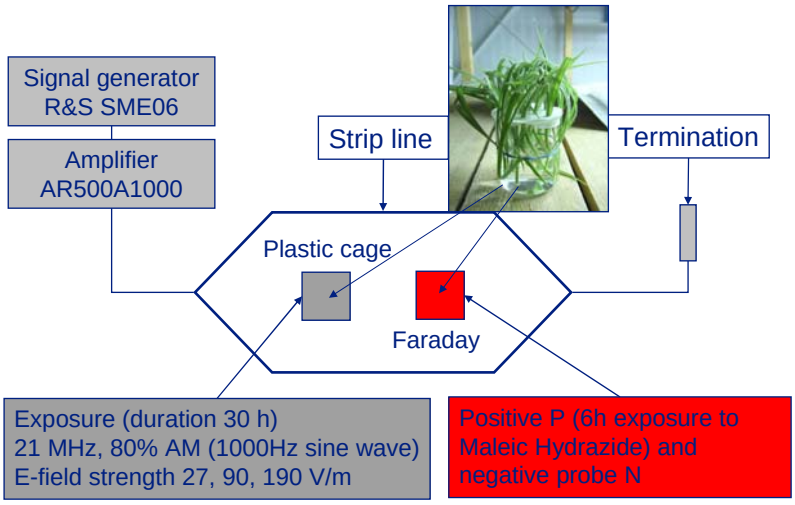
- To guarantee genetic homogeneity, plant cuttings of the clone #4430, unable to reproduce sexually, are used.
- In the early meiosis the pollen mother cells are very sensitive to genotoxic agents generating chromosome breaks.



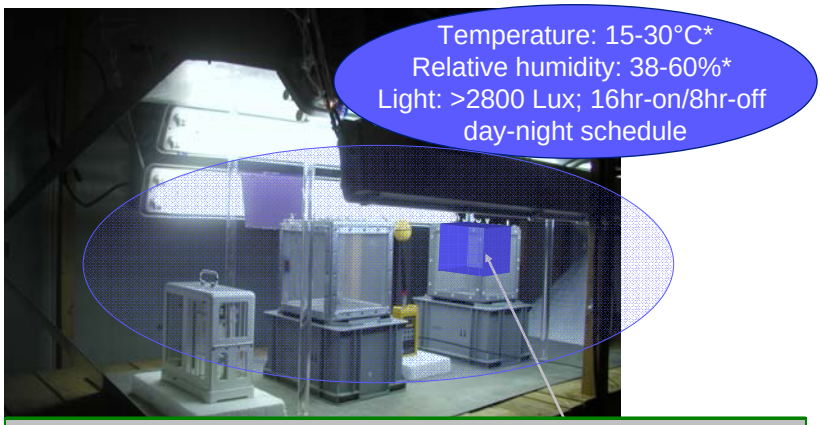
- These breaks induce micronuclei in the tetrad stage (4 celled stage of meiosis), visible under the optical microscope.
- An increase in the number of micronuclei is an indication of genotoxicity of the agent.

Ma T-H et al.; The tradescantia micronucleus bioassay. Mutation Research 1994, 310: 221-230.

The experimental set-up for the short wave exposure:



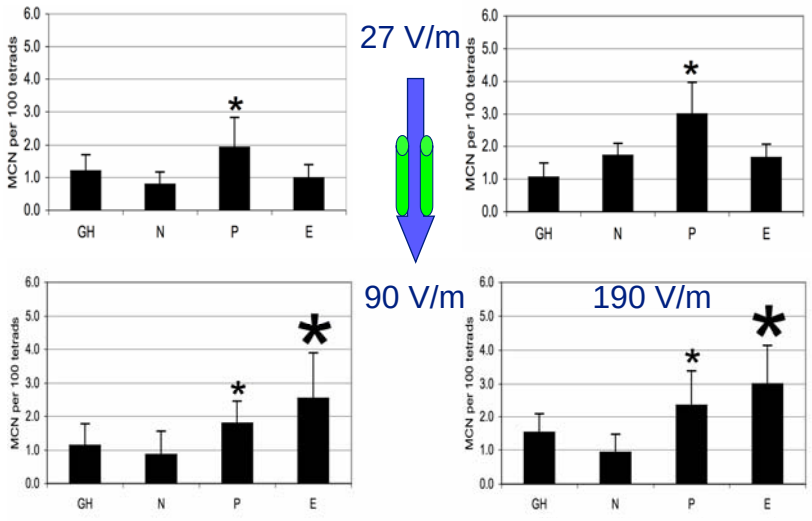
Short wave exposure set-up @ University of Hohenheim, Stuttgart:



Field polarisation	Field strengths [V/m]	Max. deviation from the average field [%]	Min. deviation from the average field [%]
vertical	27;90;190	8	-8
horizontal	90;190	6	-8

* window for all experiments, intra-experimental changes varied less than 5%

Results: Short wave exposure 21 MHz E-field vertical



Results: Short wave exposure 21 MHz E-field horizontal

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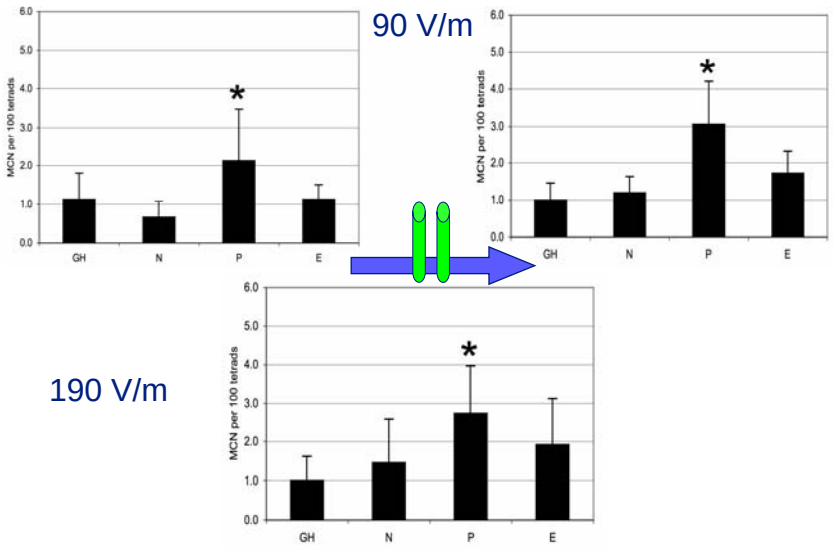

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What is the dose inside the plant?

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- The incident external field is only poorly related to the induced fields and absorbed energy in the plant tissue:

$$SAR = \frac{\sigma_{el}}{\rho} E_{\text{int}}^{\ 2} = c \cdot \left.\frac{dT}{dt}\right|_{t=0} \cong c \cdot \left.\frac{\Delta T}{\Delta t}\right|_{\Delta t}$$

- ➢ Measure the E-field inside the plant
- ➢ Measure the temperature increase inside the plant
- ➢ Numerical simulation

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SAR evaluation by numerical modelling: simplified model

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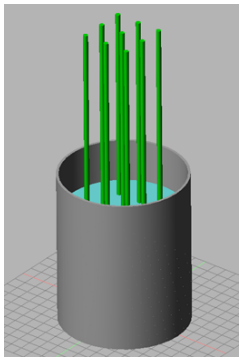
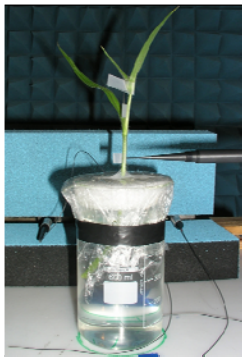


- 9 cylinders modelling the plants
- nutrient solution (water)
- glass
- Planar incident field
- FDTD
- Validation by measurements@940 MHz



Incident E-field strength 82 V/m	SAR values [W/kg]	
Measurement point	Model	Exp.*
Central plant 13.5cm	1.8	2.3
Central plant 11cm	1.4	1.3

**S. Kühn, N. Kuster, Dosimetric evaluation of RF signals on tradescantia plants, report 2006*

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SAR evaluation by numerical modelling:

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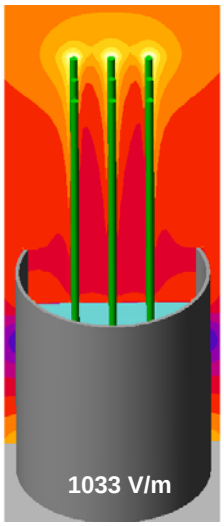

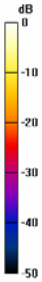

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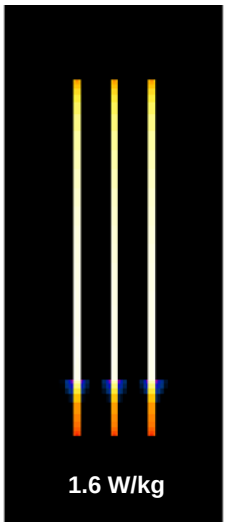

- ν=21 MHz
- E=90V/m
- Polarisation // plant axis
- Plant tissue parameters*:
  - ε_r=65
  - σ=0.47

** M.H. Broadhurst et al. Journal of Molecular Liquids 36: 65–73.*

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SAR values for the different exposure scenarios:

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Vertical polarisation	SAR values [W/kg]	
Incident E-field strength [V/m]	Mean (SD)	Max
190	3.3 (2.0)	7.0
90	0.7 (0.5)	1.6
27	0.07(0.04)	0.14

Horizontal polarisation	SAR values [W/kg]	
Incident E-field strength [V/m]	Mean (SD)	Max
190	0.1 (0.1)	0.4
90	0.02 (0.03)	0.09

- Significant increases in MCN frequencies are only observed for high SAR values (SAR higher 0.4 W/kg).
- For the E-field vector orthogonal to the plant axis the SAR values are one order of magnitude lower than for the polarisation vertical to the plant axis.

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The experimental set-up for GSM exposure:

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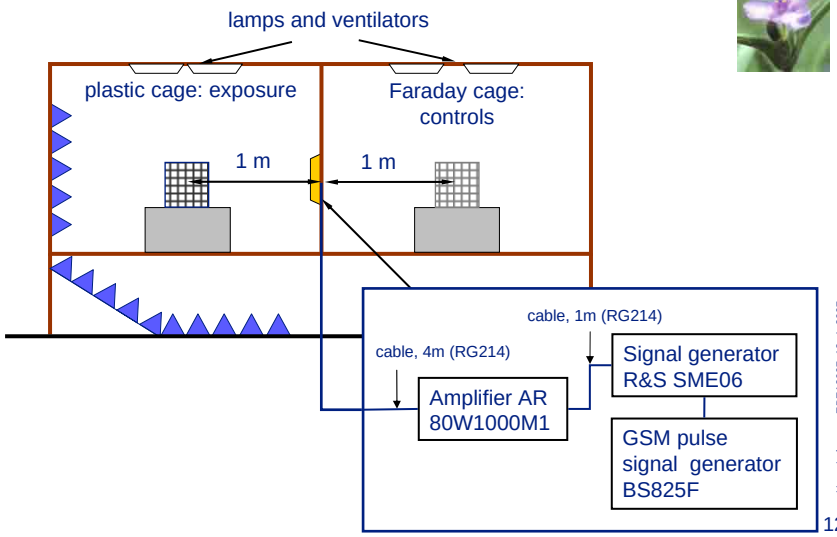

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Exposure in the GSM experiments:

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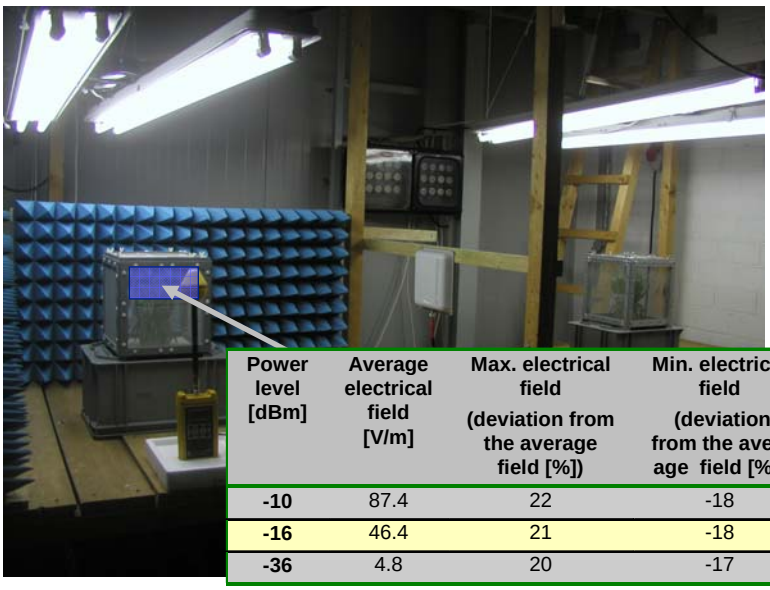

Power level [dBm]	Average electrical field [V/m]	Max. electrical field (deviation from the average field [%])	Min. electrical field (deviation from the average field [%])
-10	87.4	22	-18
-16	46.4	21	-18
-36	4.8	20	-17

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Results GSM (selection):

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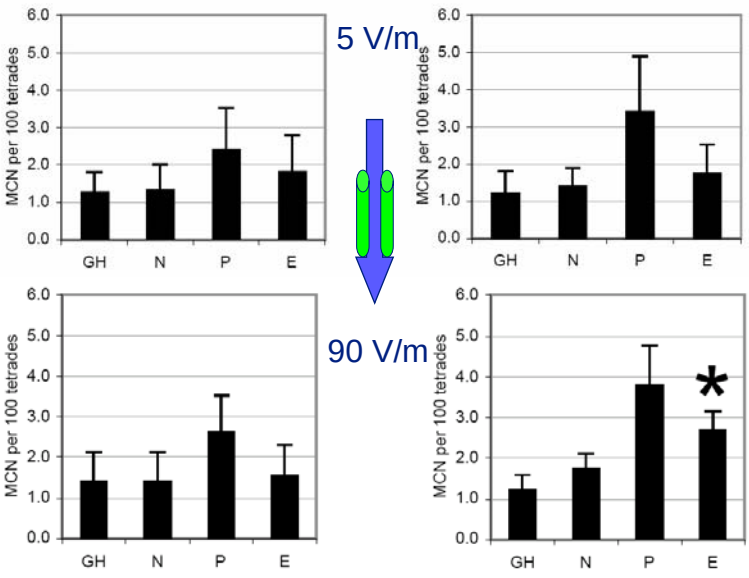

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Temperature increase?

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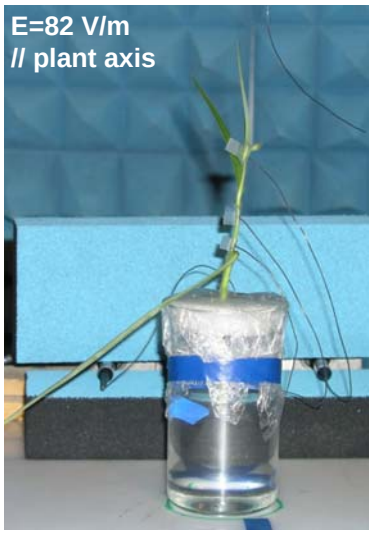

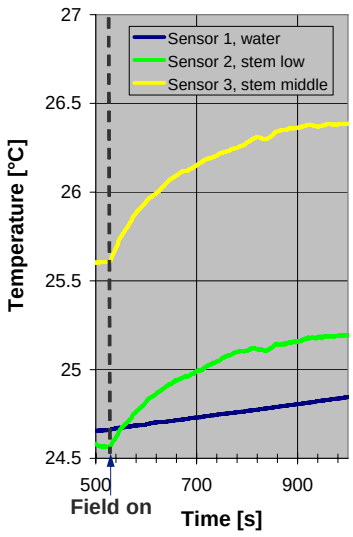

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Conclusions and open questions:

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- Above certain field strengths the MCN numbers can be elevated.
- For short wave exposure significantly increased MCN frequencies are only observed for average SAR values higher than 0.4 W/kg.
- For GSM the results are less consistent.
- Temperature measurements indicate that for high external field intensities a thermal effect cannot be excluded. Thermal stress reaction of the plant?

➢ What does a SAR value of 1W/kg mean for the plant?

➢ Further SAR calculations and thermal simulations are planned to better understand the observed pattern in the GSM (and UMTS) exposure experiments.

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