Free and/or bound water by dielectric measurements

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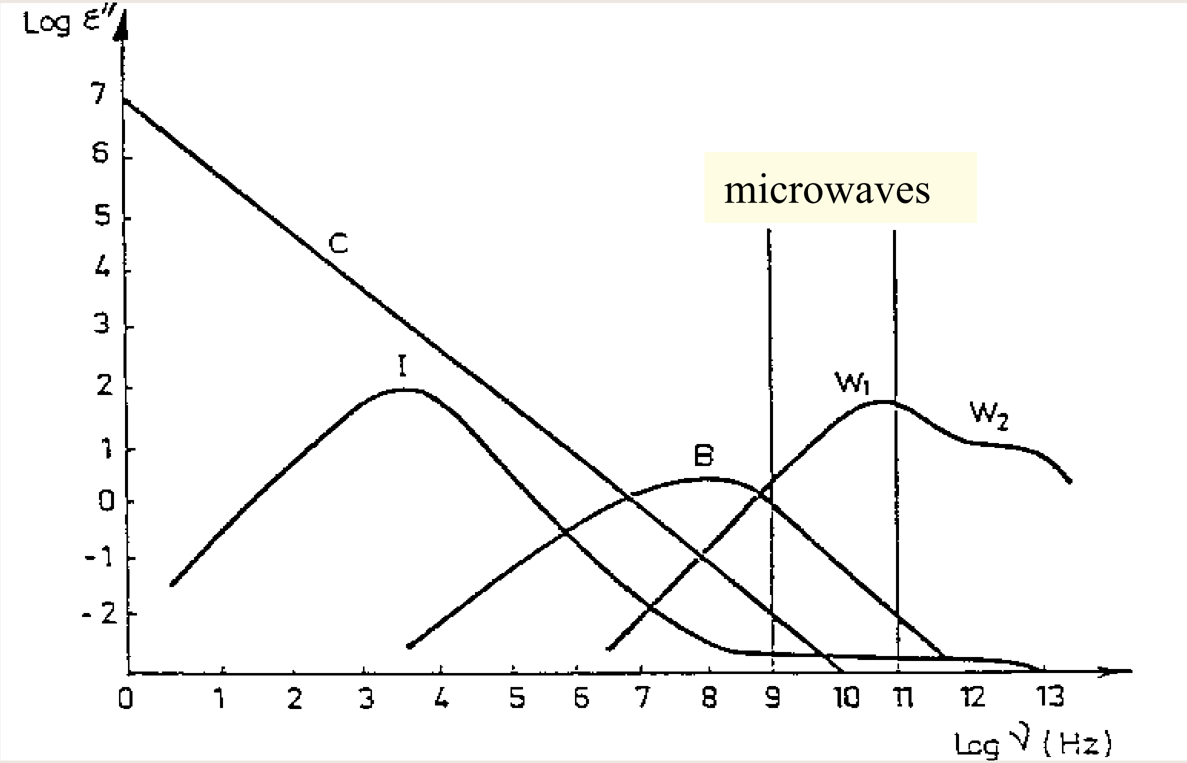
Dielectric properties of Water

$\varepsilon^* = \varepsilon' - i\,\varepsilon''$



- I kHz domain : Solid Water (ice)
- B MHz domain : Bound or Adsorbed Water
- W GHz domain : Free Water
- C Contribution of the conductivity

Additive Wiener law

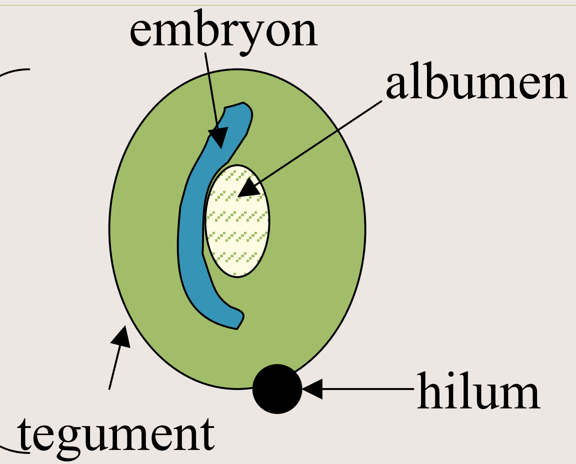
Seed

Composite material

matrix = mat

bound water = bw

free water = fw



Using Wiener law we postulate :

a) the addition of dielectric contributions

b) no dependence with the morphology

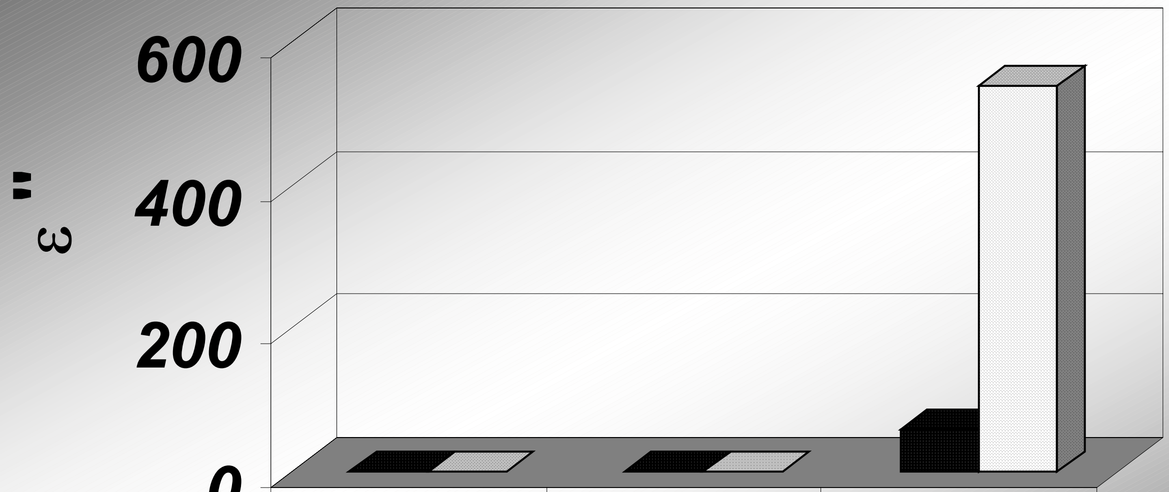
$$\varepsilon'' = \varepsilon''_{mat} \cdot \varphi_{mat} + \varepsilon''_{bw} \cdot \varphi_{bw} + \varepsilon''_{fw} \cdot \varphi_{fw}$$

$$\varepsilon' = \varepsilon'_{mat} \cdot \varphi_{mat} + \varepsilon'_{bw} \cdot \varphi_{bw} + \varepsilon'_{fw} \cdot \varphi_{fw}$$

Dielectric properties at 25°C, 5 GHz and 50% of humidity (simulation)

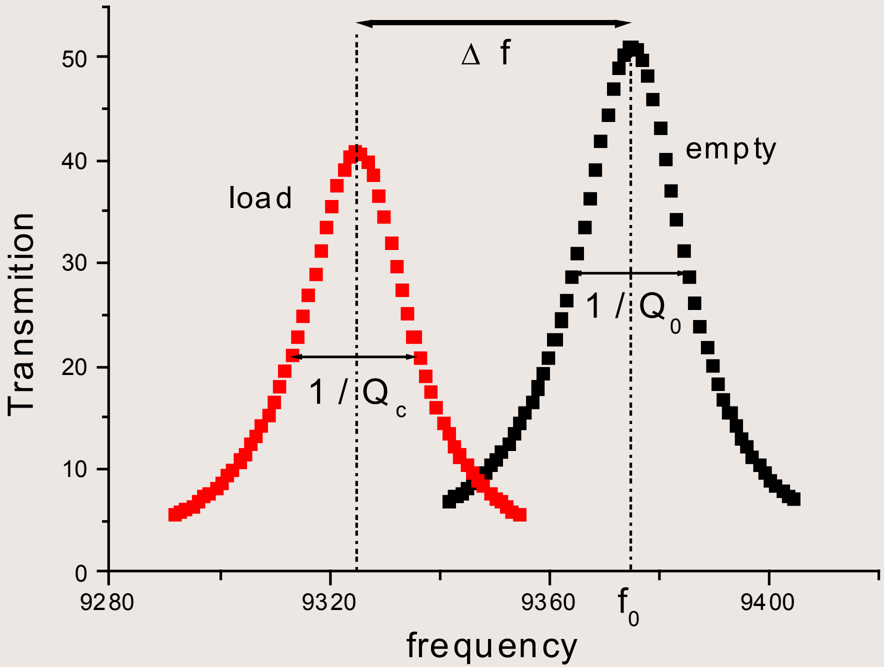
			Living seed			Death seed		
	ε’	ε’’	%	partial ε’	partial ε’’	%	partial ε’	partial ε’
Matrix	3	0.01	80	2.4	$0.8\ 10^{-2}$	80	2.4	$0.8\ 10^{-2}$
Bound water	10	0.1	18	1.8	$1.8\ 10^{-2}$	2	0.2	$0.2\ 10^{-2}$
Free water	70	30	2	1.4	$60\ 10^{-2}$	18	12.6	$540\ 10^{-2}$
Total				**5.6**	**$62.6\ 10^{-2}$**		**16.2**	**$541\ 10^{-2}$**

Discrimination using ε''



	Material	Bound	Free
Living	0.8	1.8	60
Death	0.8	0.2	540

Small perturbation theory

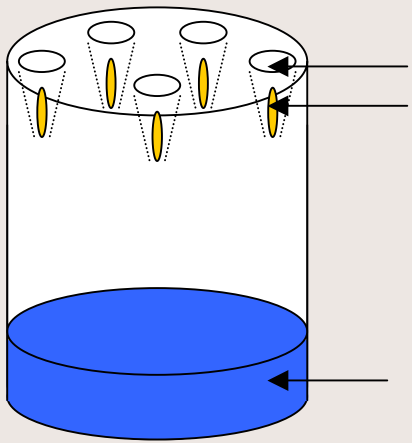


$$\left(\varepsilon'-1\right)\frac{v}{V}=K\frac{\Delta f}{f_0}$$

$$\varepsilon''\frac{v}{V}=\frac{K}{2}\Delta\left(\frac{1}{Q}\right)$$

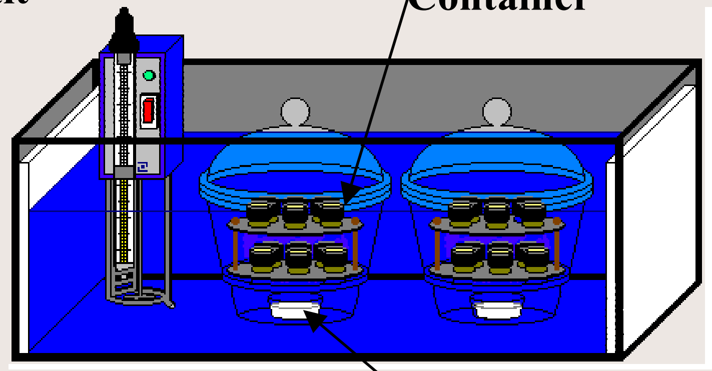
v = Volume of the sample
V = Volume of the cavity
K = Depolarisation
or coupling factor

Conditioning the seeds of tomatoes

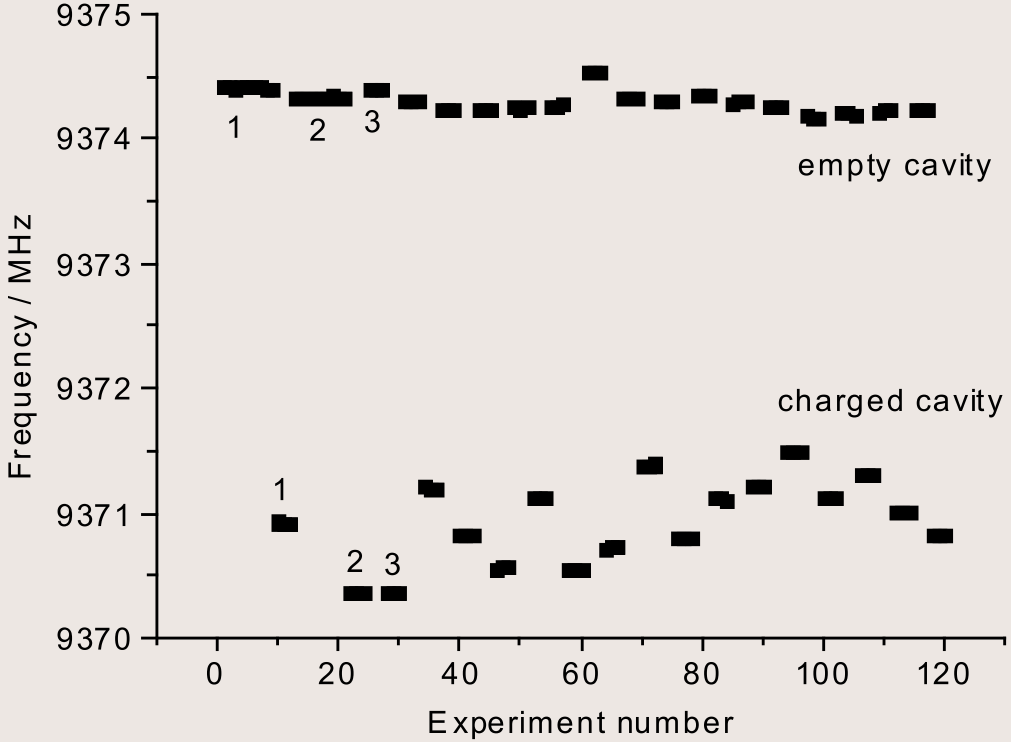


T=25°C

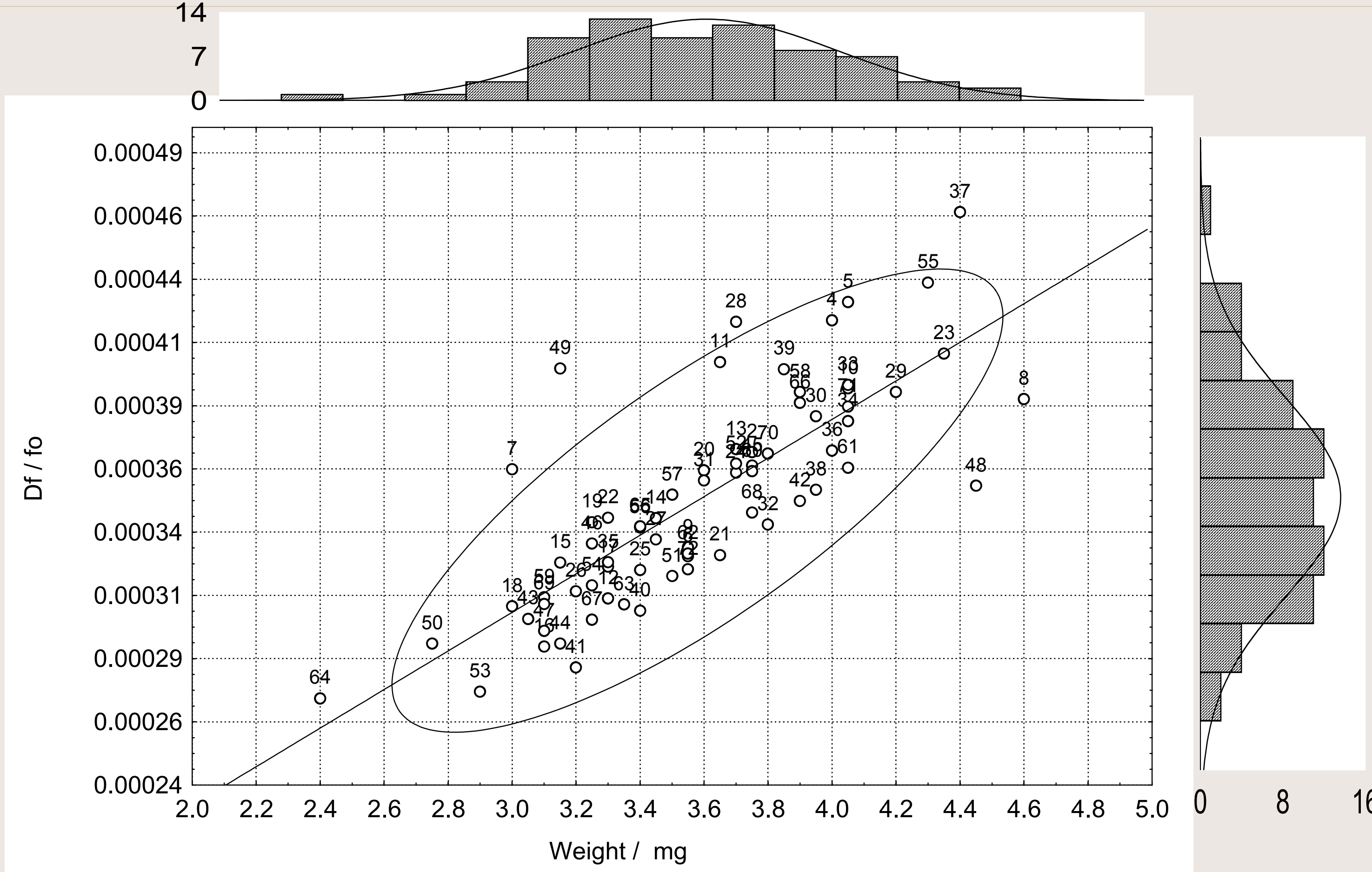
RH=50%



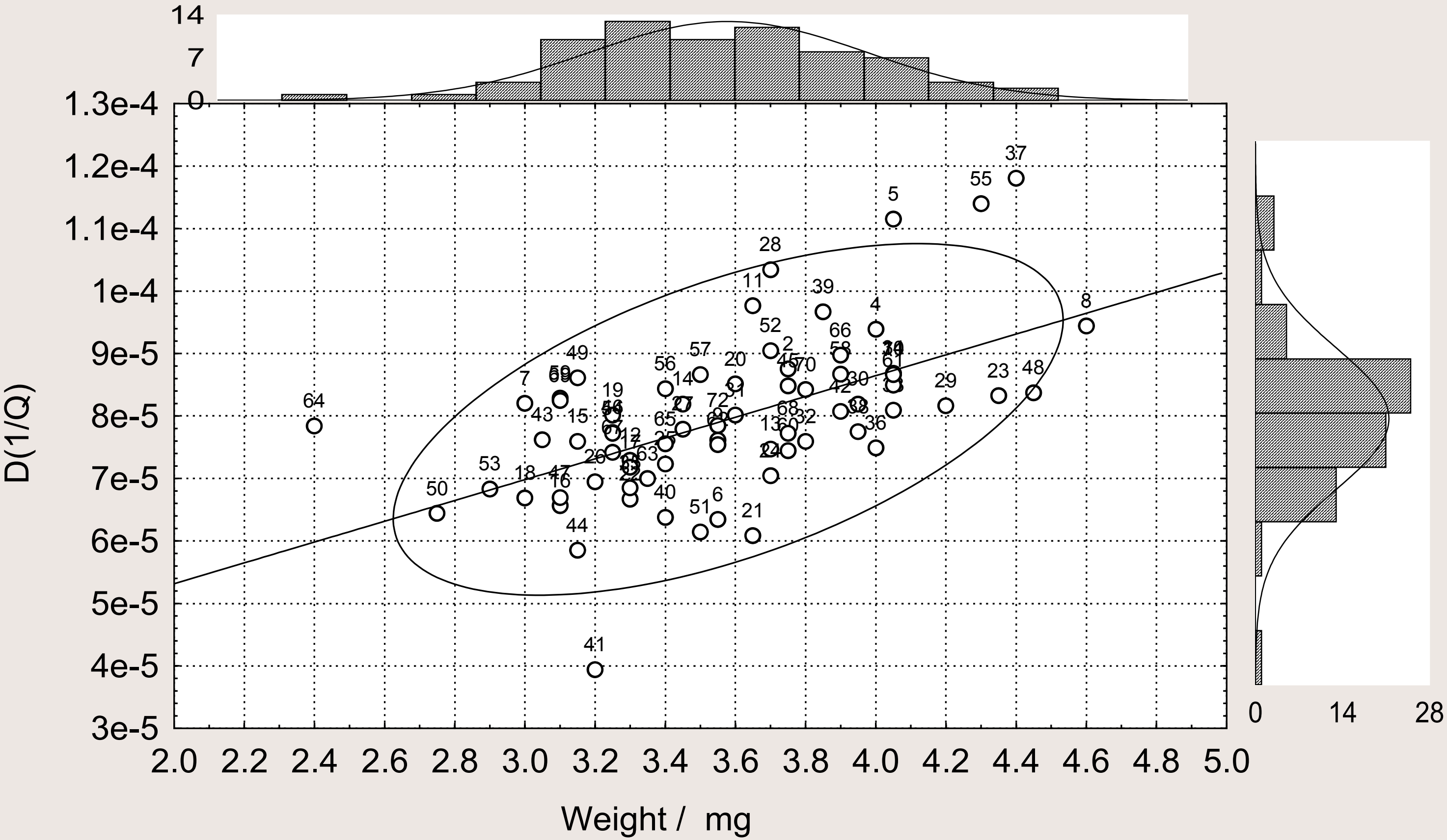
Charging the cavity



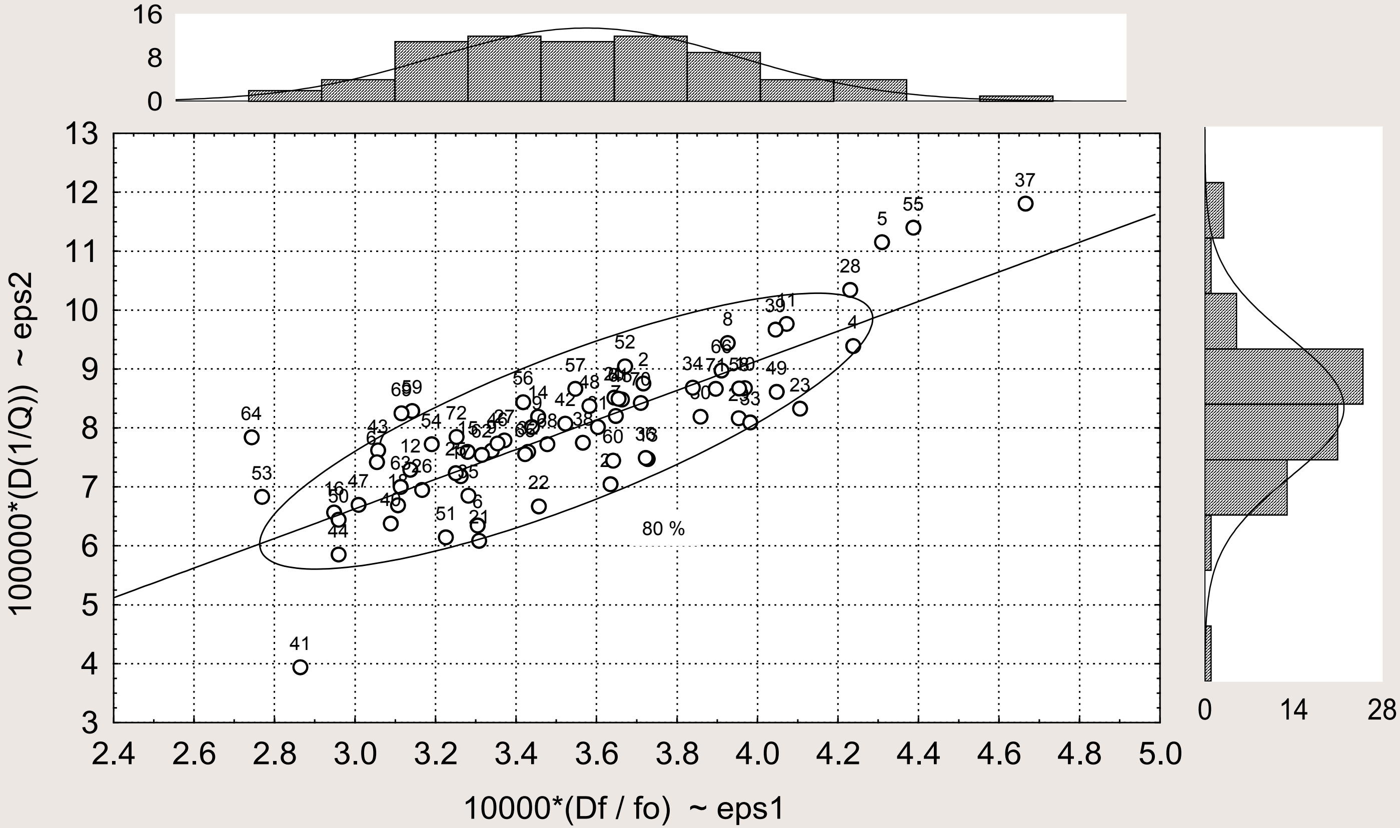
Δf/f_0 versus weight (tomatoes)



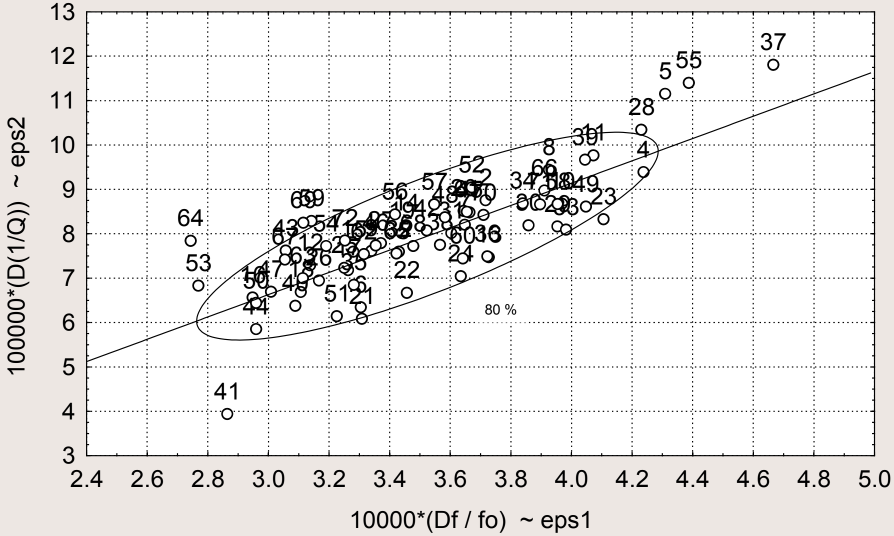
Δ(1/Q) versus weight (tomatoes)



Statistical ellipsoid



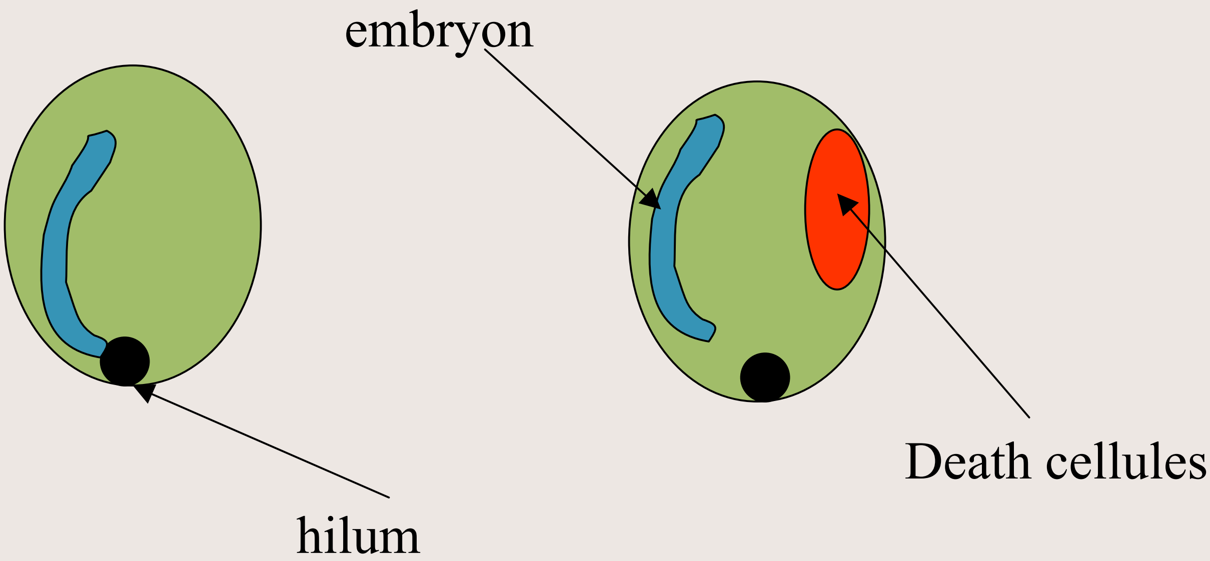
1st Criterion of elimination



The seeds outside the ellipsoid of statistical dispersion are probably death!

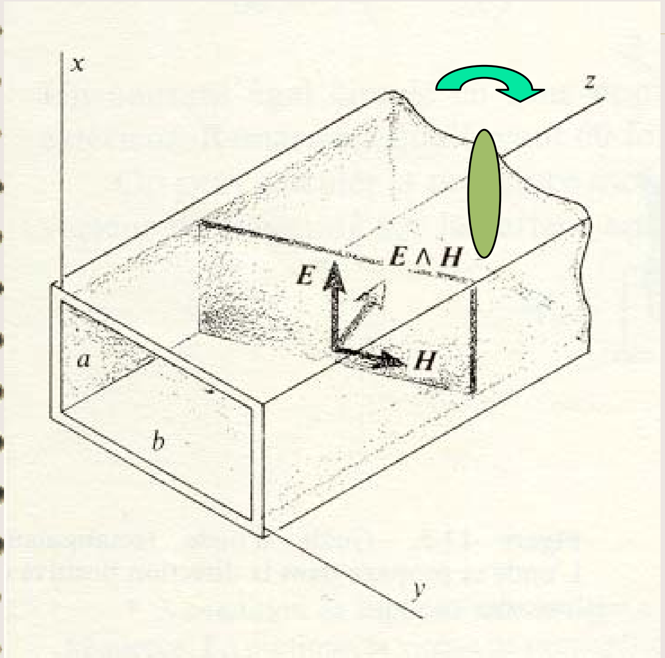
Anisotropy of tomato seed

a) asymmetric morphology
b) dielectric heterogenity



Death cellules → Increasing of heterogenity → Anisotropy

Resonant cavity

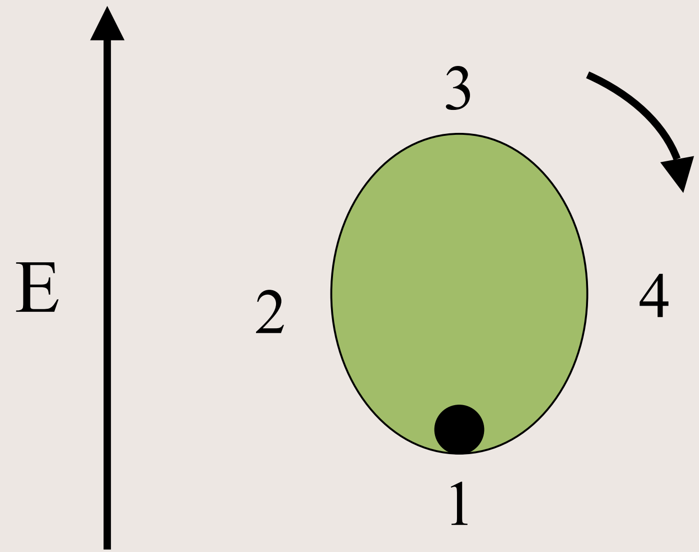


E is strongly polarised

The rotation of seed show us, with the measurement of variation of coupling factor (K), the anisotropy or dielectric heterogenity

Measurement of anisotropy (elliptic disk tomatoes seed)

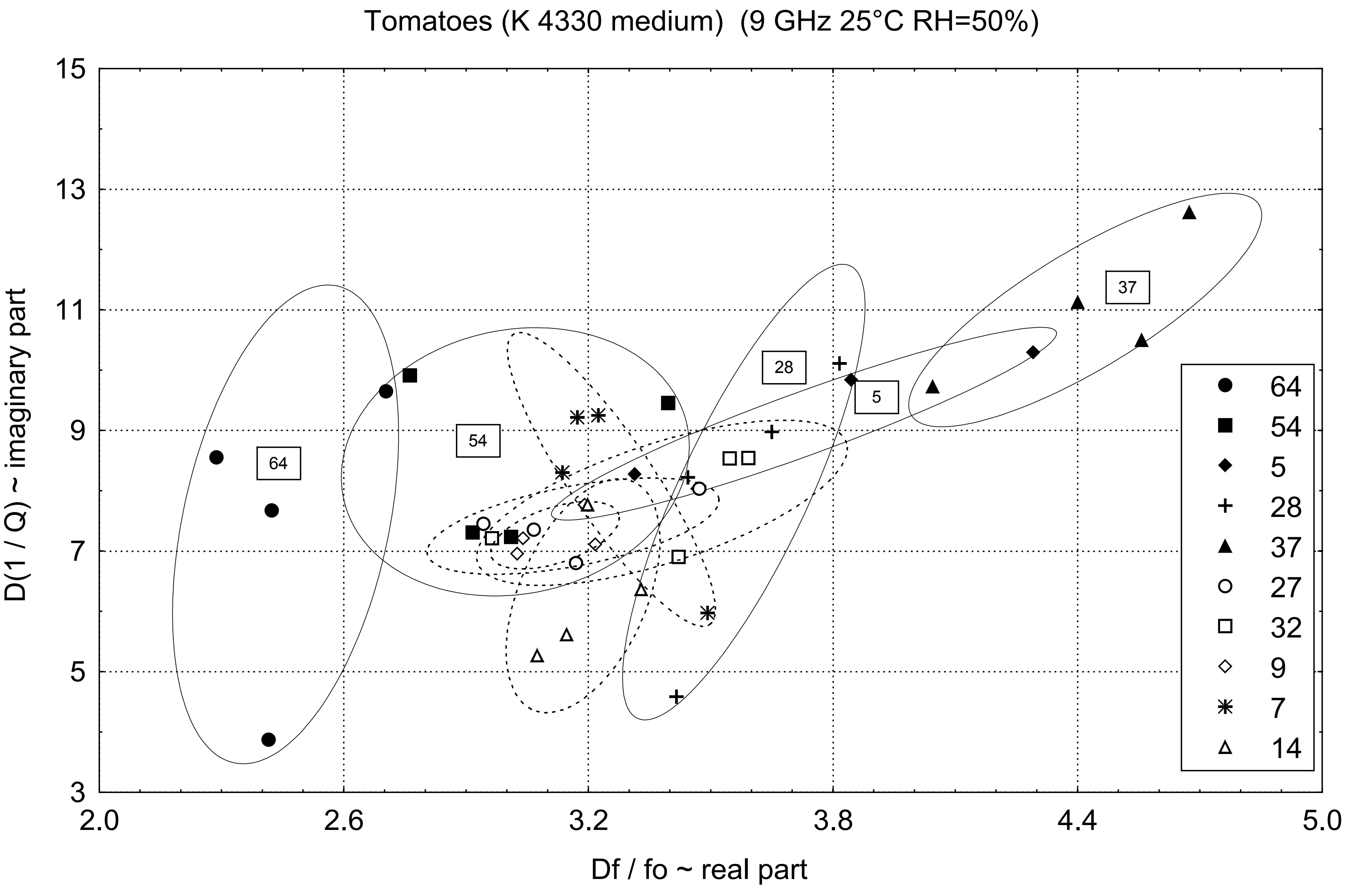
Rotation of the seed inside the cavity
(4 perpendicular positions)



In the ellipsoid distribuition we choose:

5 seeds outside + 5 seeds inside
(64,54,5,37,28) (7,9,14,27,32)

2 nd Criterion of elimination



Elimination of seeds

1 st criterion – The high quantity of death cellules (seeds outside the ellipsoid) probably implies a death seed!
2 nd criterion – The seeds (inside or outside the ellipsoid) with high anisotropy are probably death!

Conclusions

The statistical discrimination with these criterions is rather good

The germination of the seeds, from now, will confirm this discrimination (we hope!!!)

This lab methodology can be implemented in industry