Manejo sustentable de suelo, riego y nutrición.

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Focus on:

- **Mineral nutrition**
- **Irrigation**
- **Soil management**

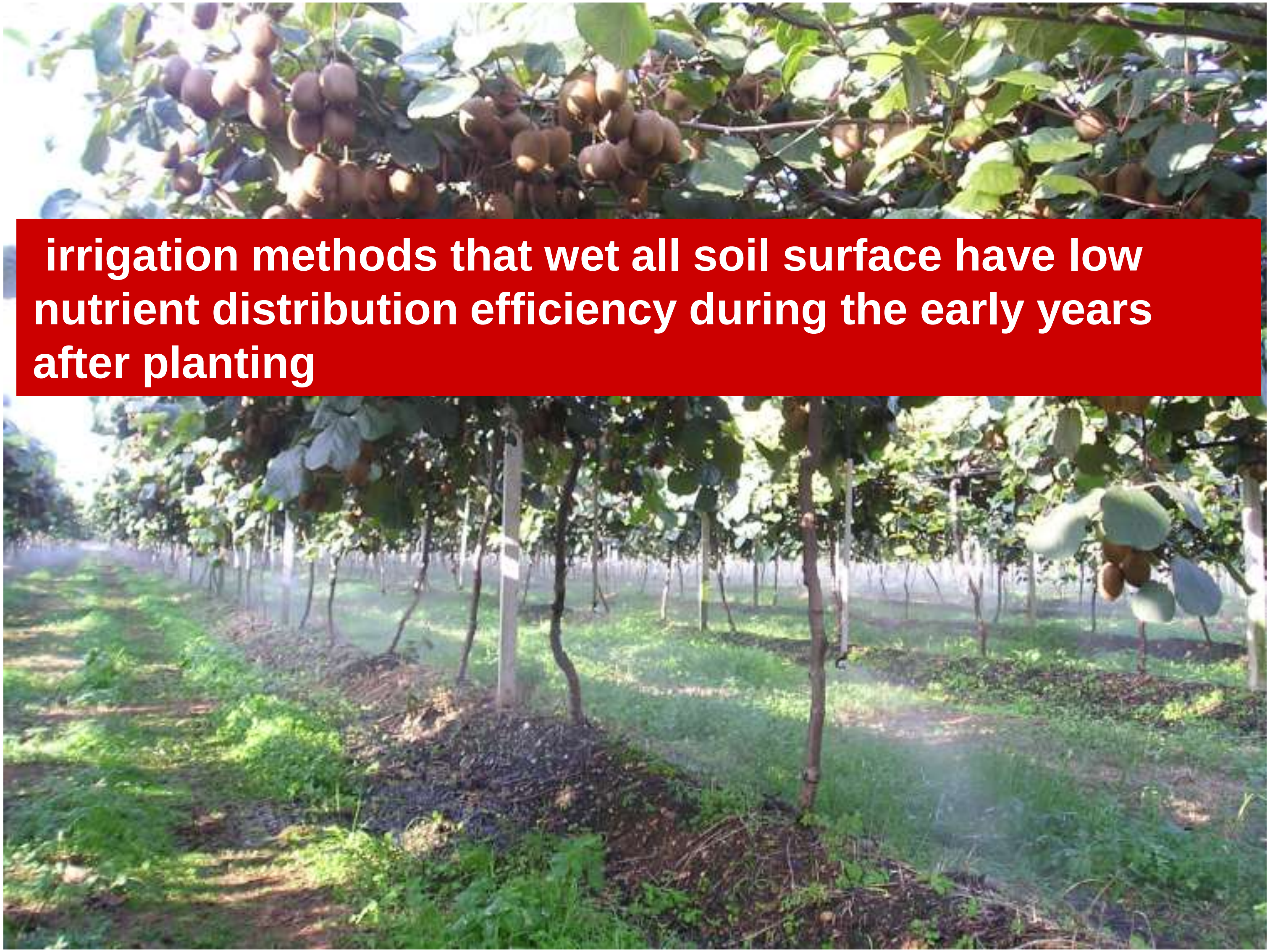
Knowledge of vine-demand to calibrate the fertilization plan

Amount of some mineral elements in whole kiwifruit vine (cv Hayward, 740 p/ha) each value is the mean of 3 plants uprooted at the end of each year.

	kg ha^{-1}				
Year from plant.	**N**	**P_2O_5**	**K_2O**	**CaO**	**MgO**
I	**4.3**	**1.6**	**3.6**	**11.8**	**2.2**
II	**20.9**	**7.4**	**18.0**	**57.8**	**10.5**
III*	**41.9**	**15.4**	**43.4**	**96.2**	**18.3**

* Yield 7 t ha-1

The distribution method should be taken into consideration to estimate the efficiency



irrigation methods that wet all soil surface have low nutrient distribution efficiency during the early years after planting

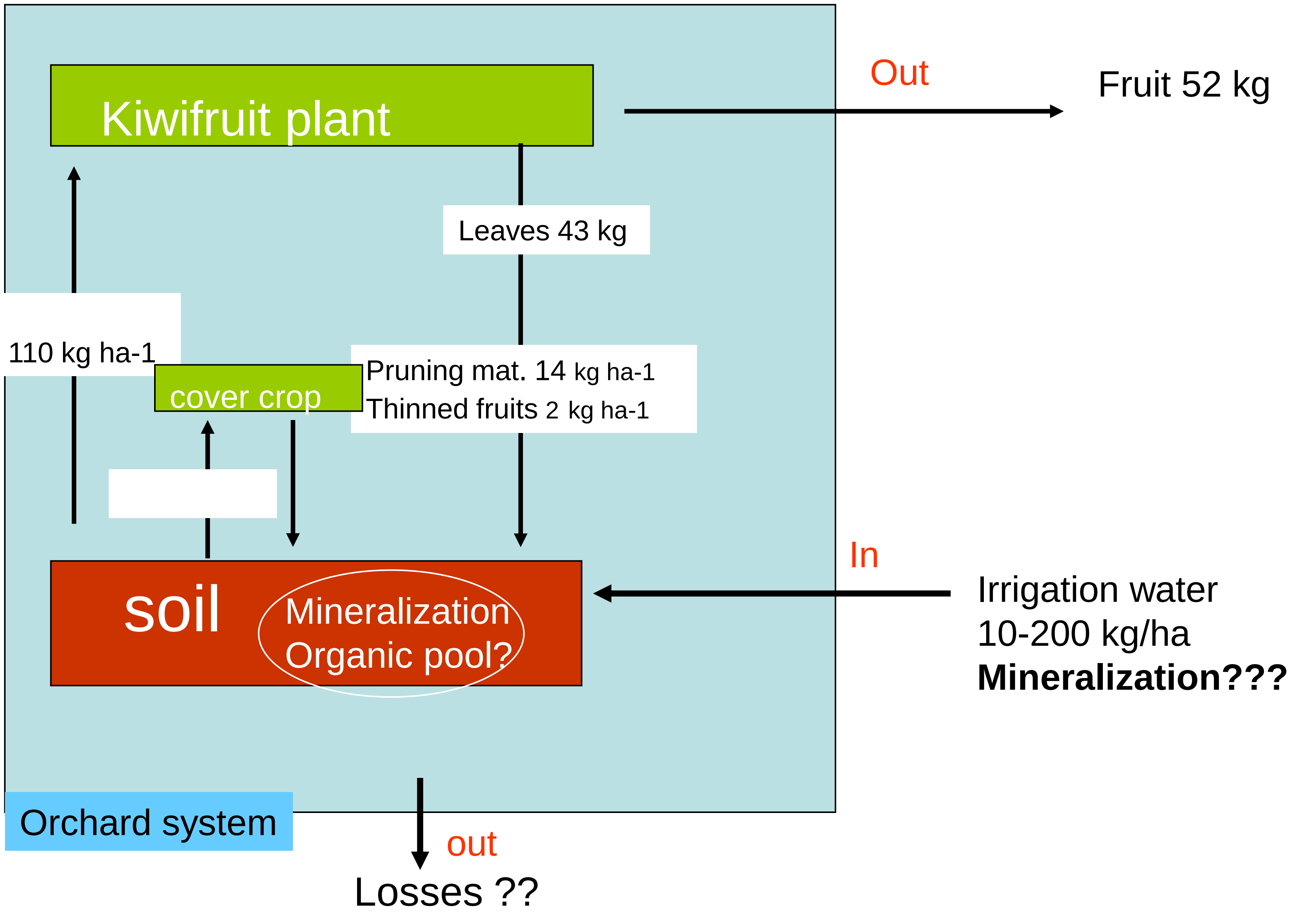
4-year average annual dry matter (DM) and nutrients partitioning among plant organs (cv Hayward, Pergola 494 p/ha, 21-year old, yield 34.2 t ha^{-1}).

	DM	N	P	K	Ca	Mg
	t /ha	Kg / ha				
Yield	5.9	52	7	95	12	10
Leaves	4.3	43	3	78	104	17
Pruning material	2.0	14	2	10	8	4
Thinned fruits	0.2	2	0.2	9	0.3	0.7
Total	**12.4**	**111**	**12.2**	**192**	**124.3**	**31.7**
OUT of Orchard	**5.9**	**81**	**7**	**95**	**12**	**10**

(Pruning material was mulched *in loco)*

Entrano con l’acqua di irrigazione (10000m3 /ha): 220 kg di N nitrico; 625 kg di Ca; 80 kg di magnesio; 24 kg di K; 167 kg di Na e 220 kg di cloro ogni anno per ettaro.

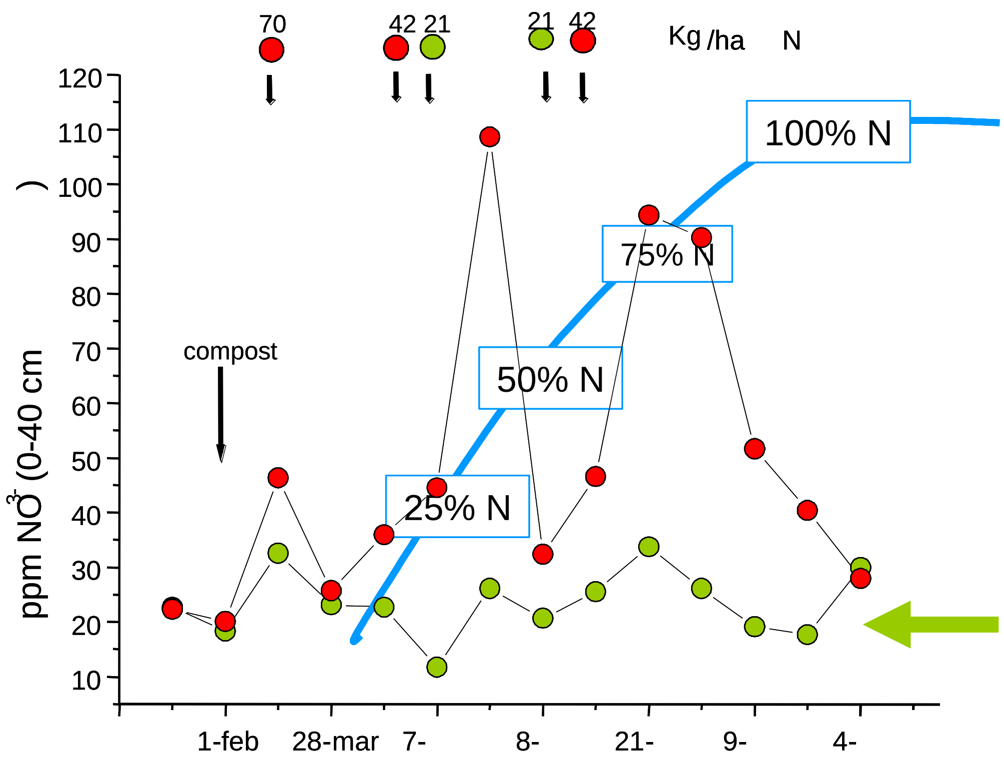
….Nitrogen flow (yield 34.2 t ha^{-1})



Caratteristiche chimiche dell’acqua di pozzo impiegata per l’irrigazione e relativo apporto di sali al suolo. (Volume irriguo annuale 12.460 m^3 ha^{-1}, campione di acqua prelevato nel mese di Giugno). (Hayward, 5 x 5 tendone)

	ANALISI CHIMICA	APPORTI
	mg L-1	kg anno
Cloruri	107.6	1340,7
Azoto da nitrati	9	112.1
Solfati	14.1	175.7
Sodio	48.7	606.8
Potassio	28.6	356.4
Magnesio	21.8	271.6
Calcio	96.1	1197.4
Bicarbonati	305	3800.3

NITROGEN fertilization: knowledge of mineralization process

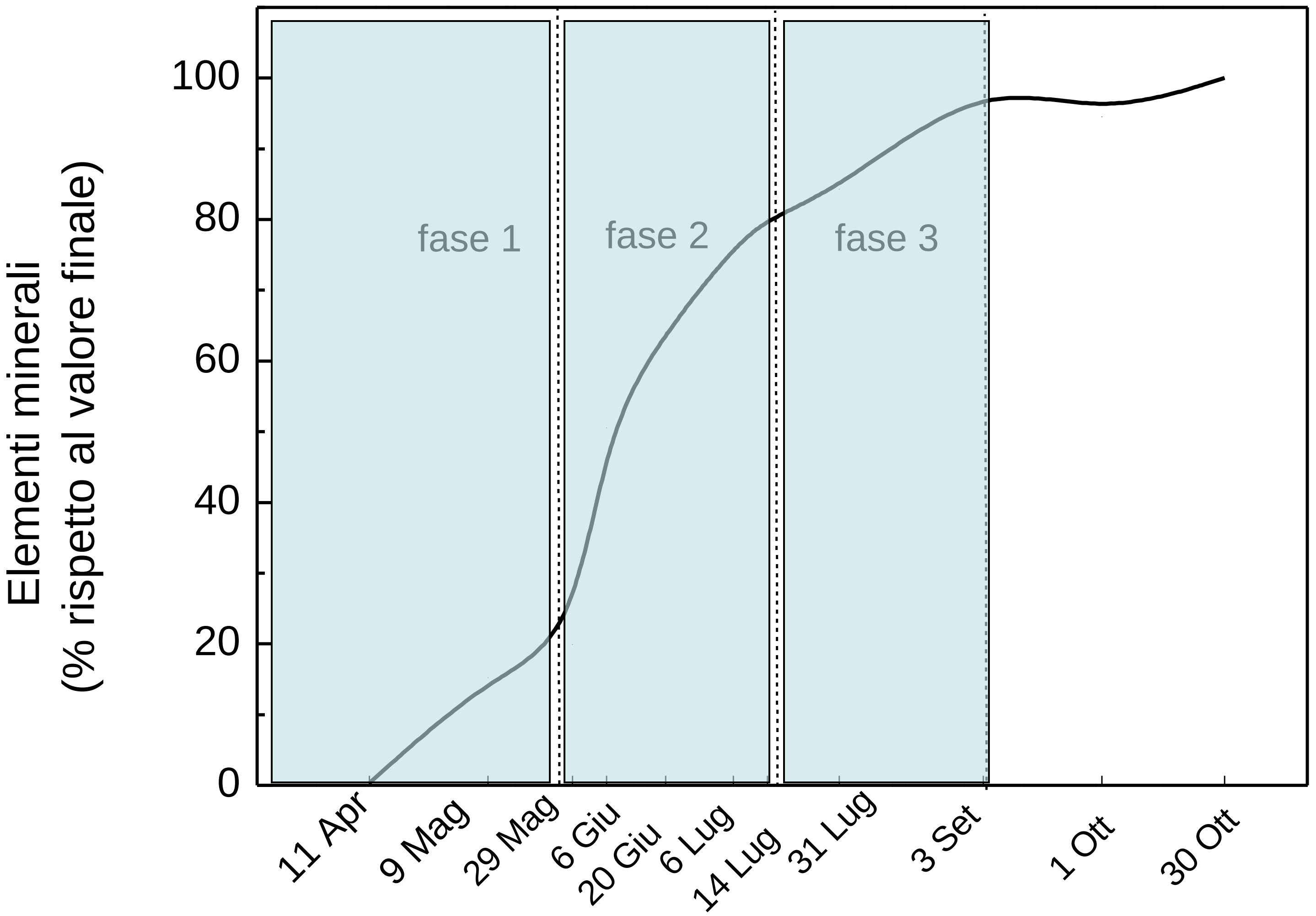


roughly stable N availability…

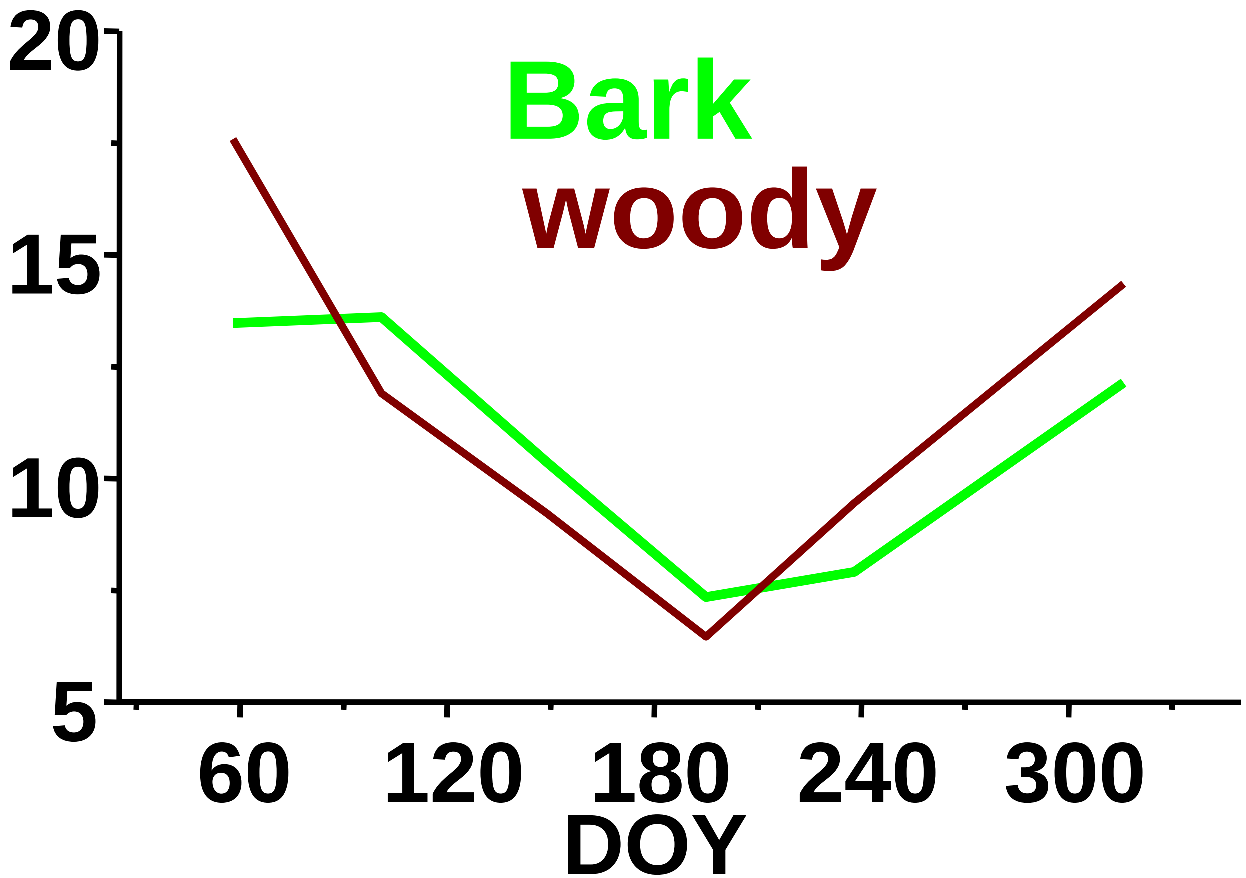
sustainable

conventional

Assorbimento medio di macronutritivi dal suolo



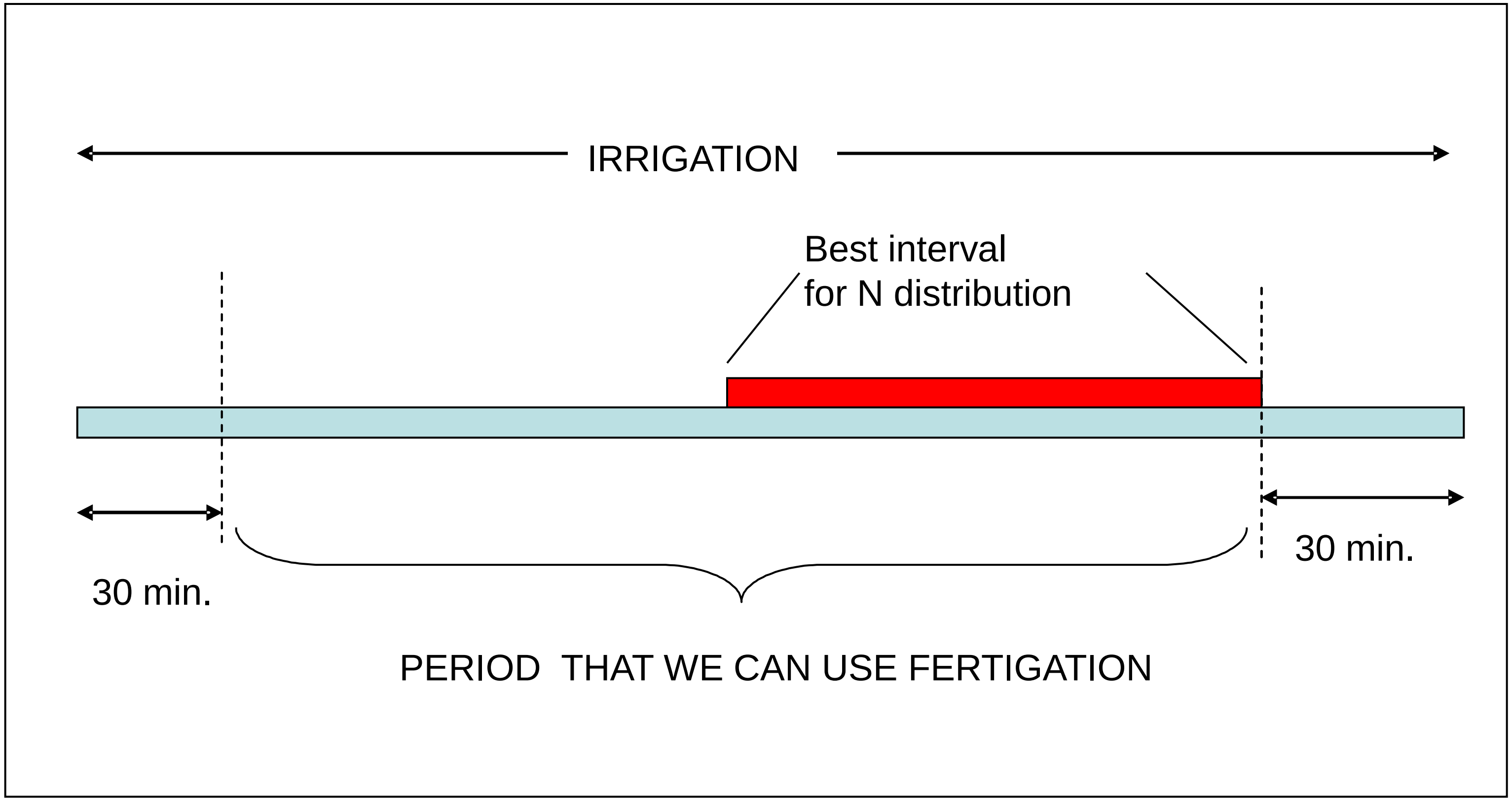
Variations of Nitrogen content storaged in shoots (kg ha^{-1}) in a mature kiwifruit orchard (pergola, 625 t ha^{-1})

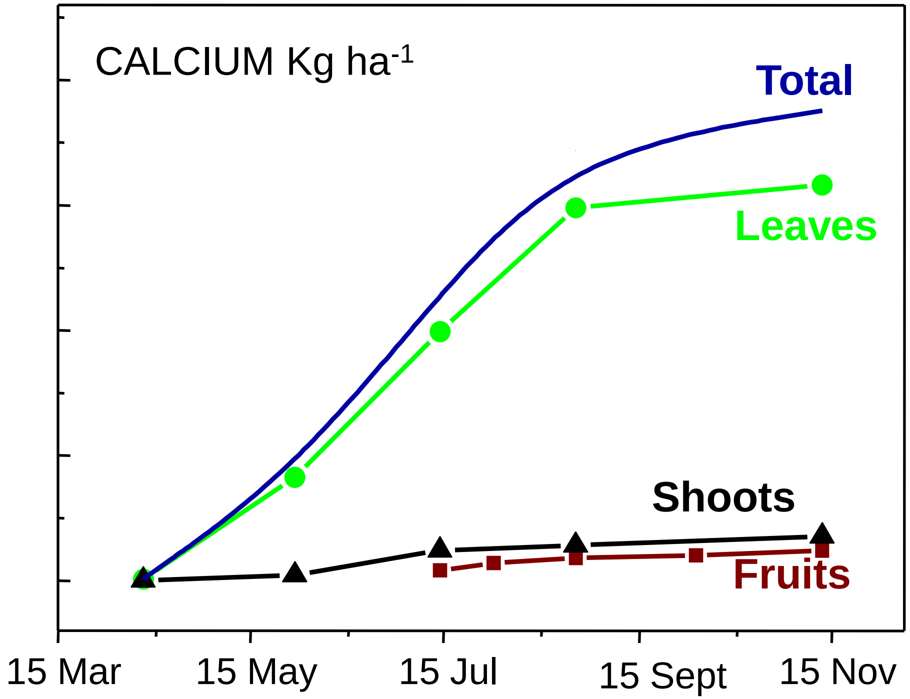


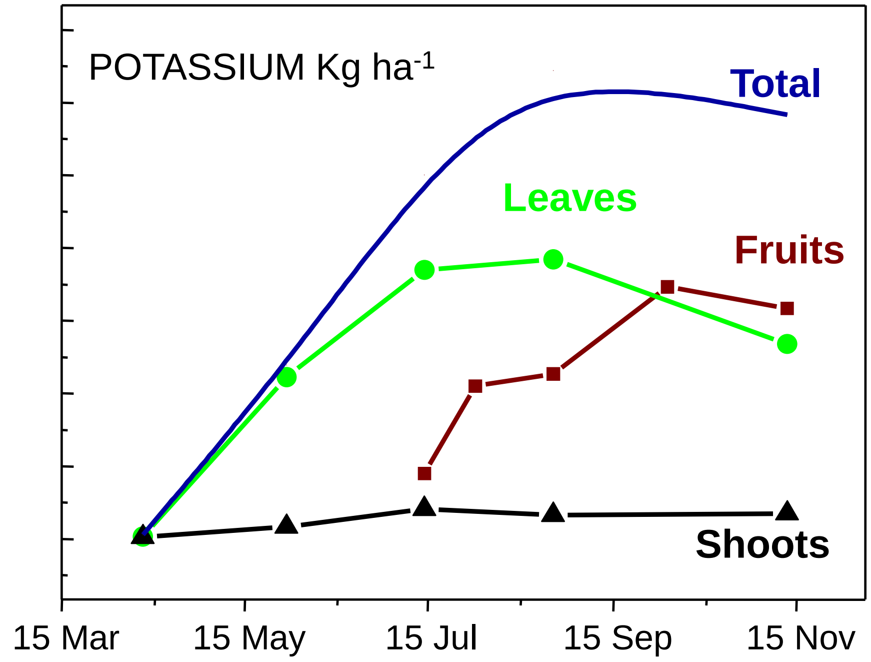
Example of fertigation plan for a mature kiwifruit orchard (% of the total)

	Weeks from bud break	N	P	K
1	4	6	20	-
2	6	6	20	-
3	8	7	20	-
4	10	7	20	-
5	11	8	20	8
6	12	8	-	8
7	13	10	-	10
8	14	10	-	10
9	15	10	-	10
10	16	6	-	10
11	17	6	-	10
12	18	6	-	10
13	19	3	-	8
14	20	3	-	8
15	21	2	-	4
16	22	2	-	4
		100%	100%	100%

Nutrients are distributed as % of the mean annual requirement accordind to vine demand along the season

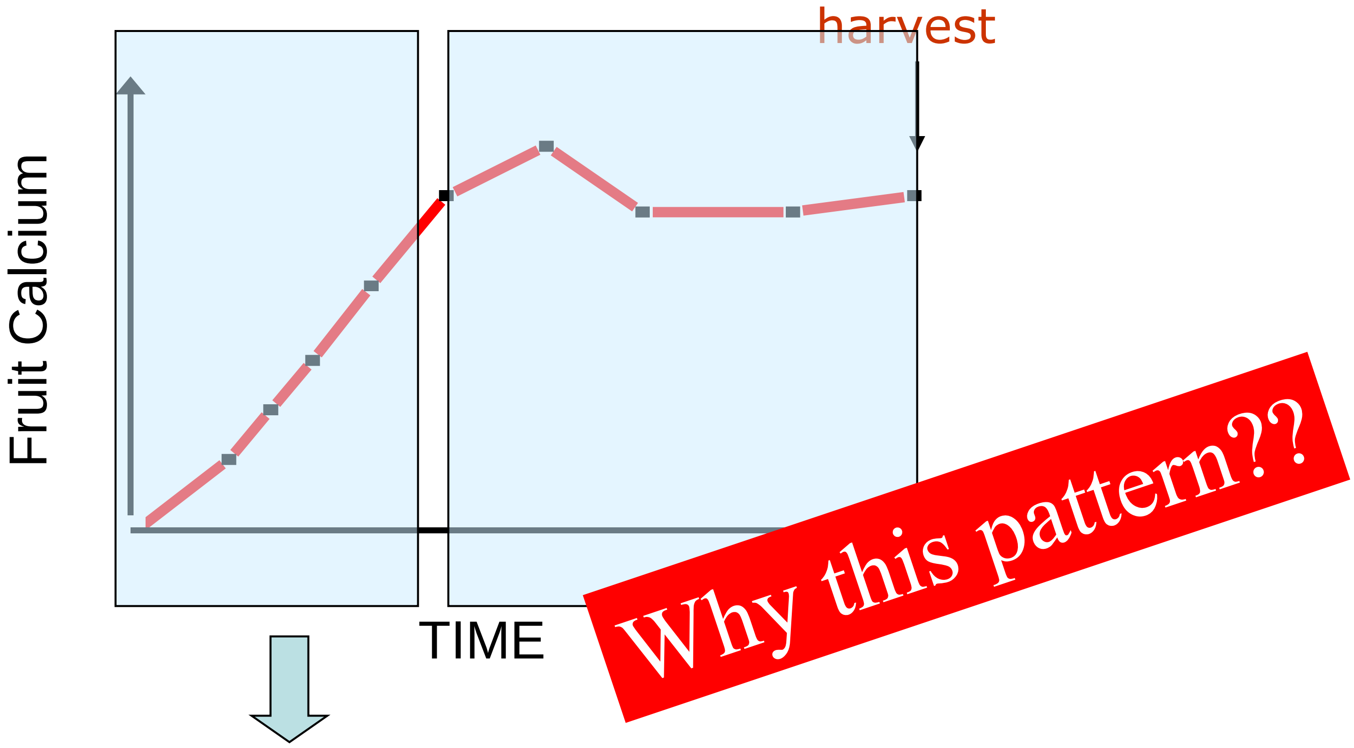

IRRIGATION
Best interval
for N distribution
30 min.
30 min.
PERIOD THAT WE CAN USE FERTIGATION





Seasonal calcium and potassium demand and partitioning in the different plant organs (mature kiwifruit orchard 625 p ha^{-1})

…. Ca accumulation into fruit



8-9 weeks
After Fruit Set
(AFS)

Leaf transpiration…

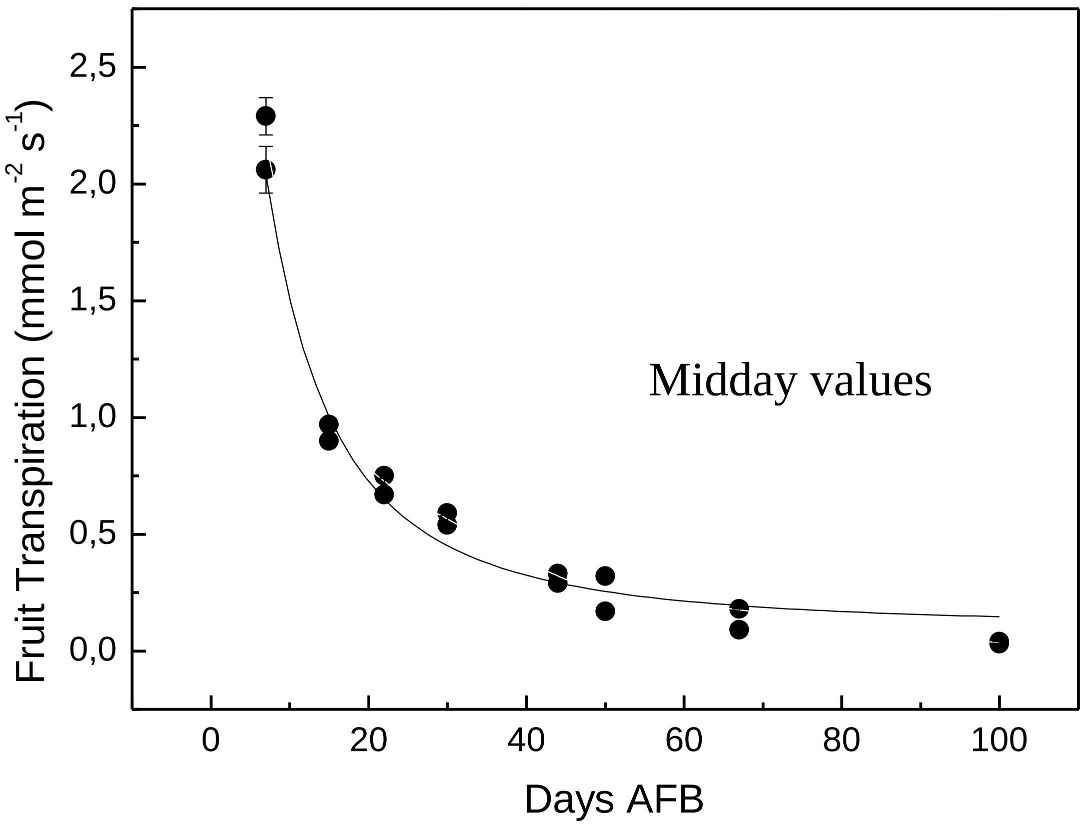
- **Affect plant water consumption**
- **the centre of photosynthetic capacity** (Bodribb, Plant Sci, 2009)
- **…impact on yield**
- **…….**

→ **Very small (0.5% of total transpired water)**

Fruit transpiration…

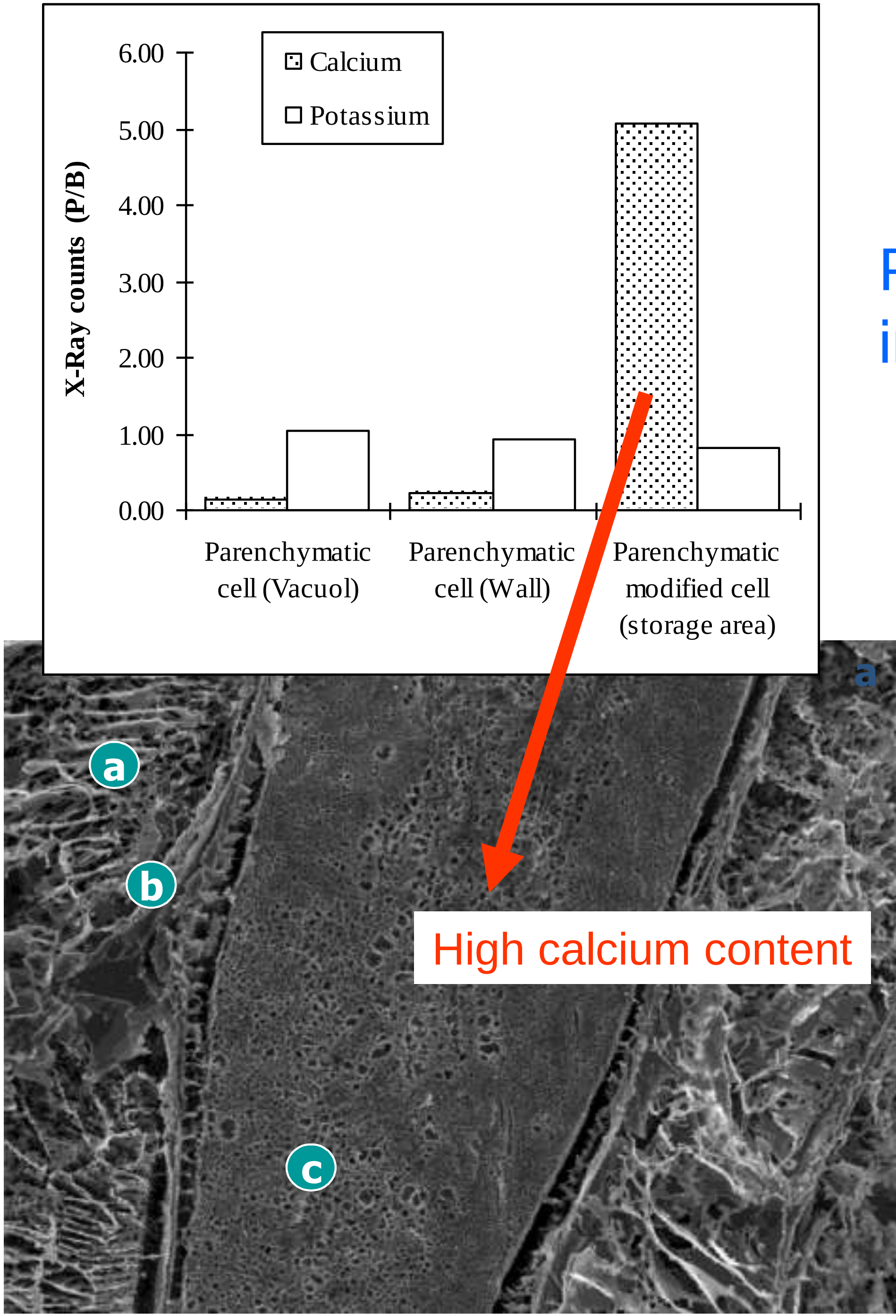
→ **Ususally fruits effect leaf transpiration**
(from 15 to 30% xiloyannis, Naor)

→ **Impact on fruit quality**
(i.e. mineral composition)



(Montanaro et al., 2006)

…. on attached fruit



Part of the total Ca is stored in specialised cell …..

(by Vitagliano et al., 1999)

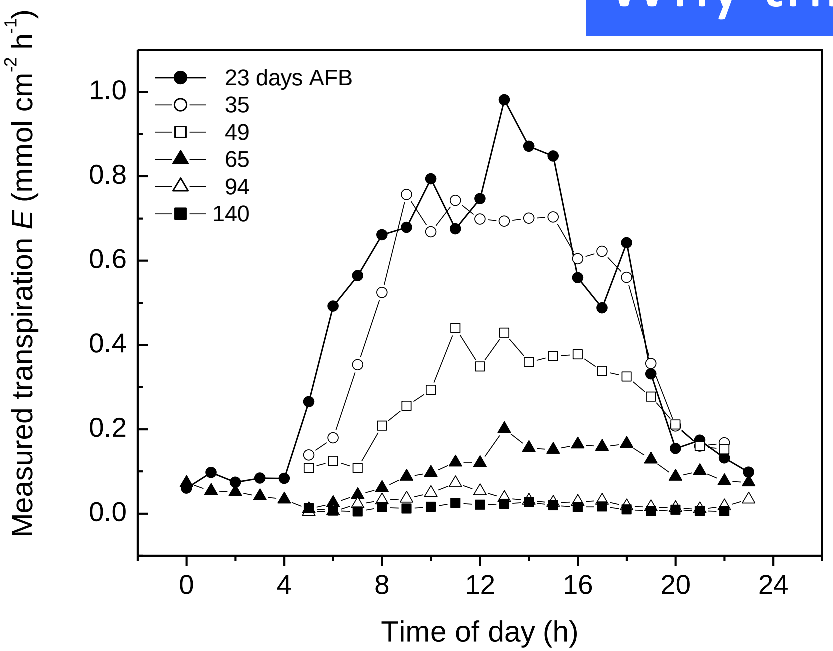
How Ca naturally reach the fruit?? *A causal chain…*

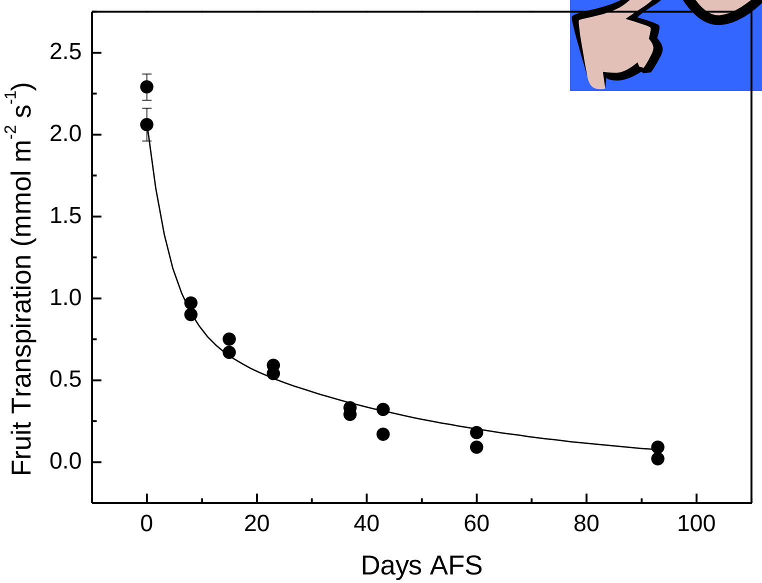
→ Transpiration → Xylem stream → Ca

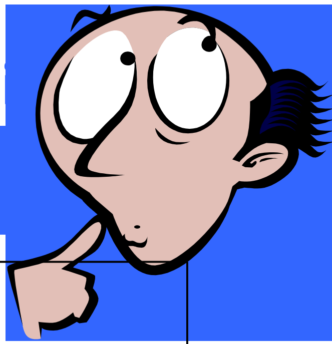
…some features of fruit transpiration

- diurnal/seasonal pattern
- higher in young fru

Why this trend?

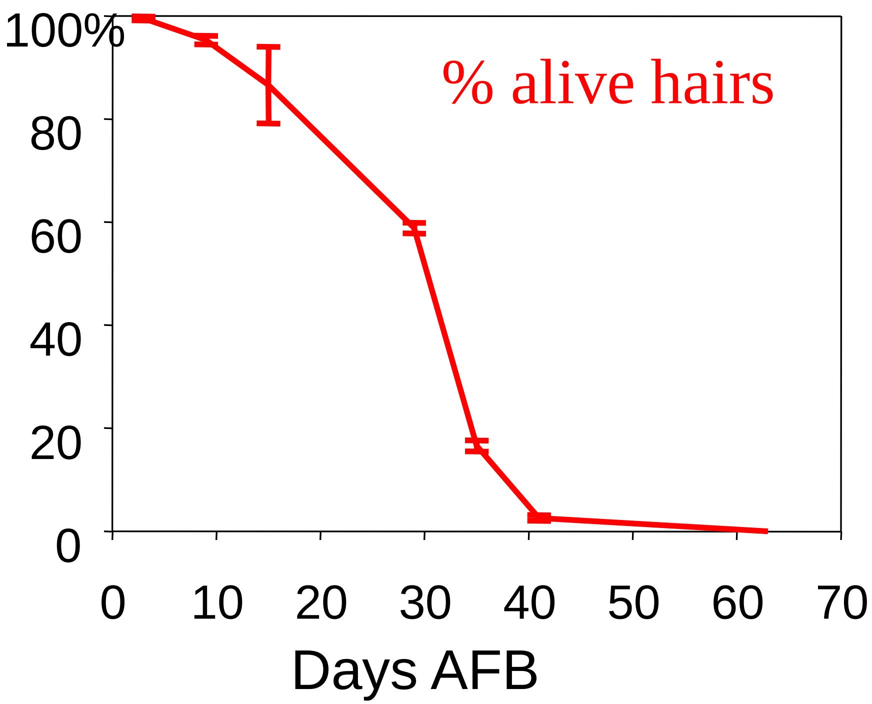


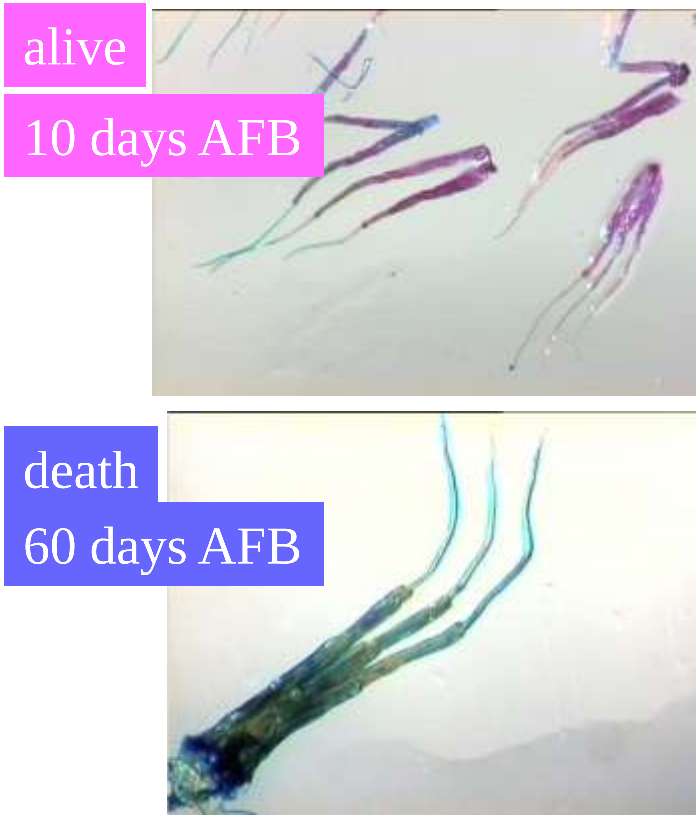




Montanaro et al Plant Sci 2006

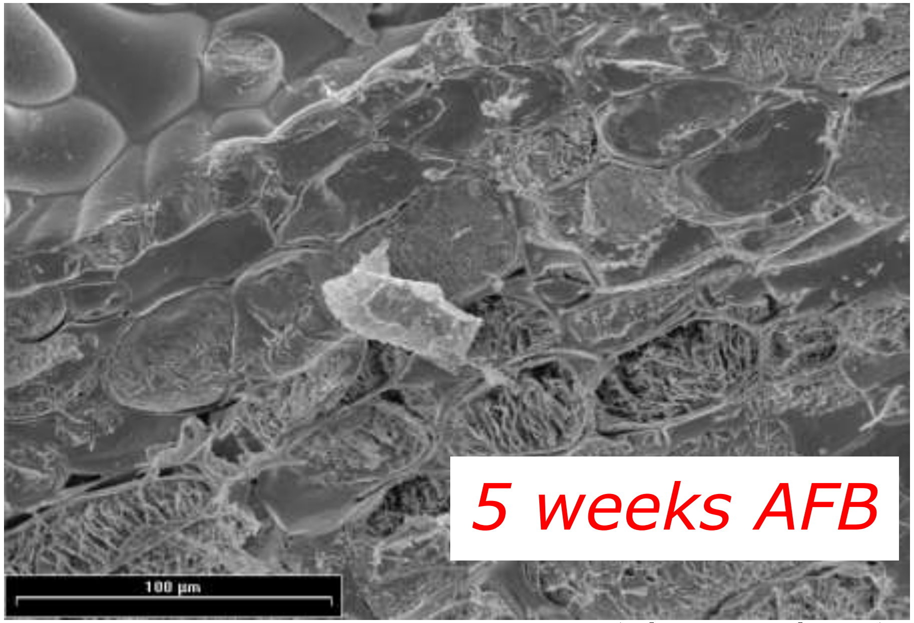
…fruit transpiration decrease with changes of: **Hairs viability**



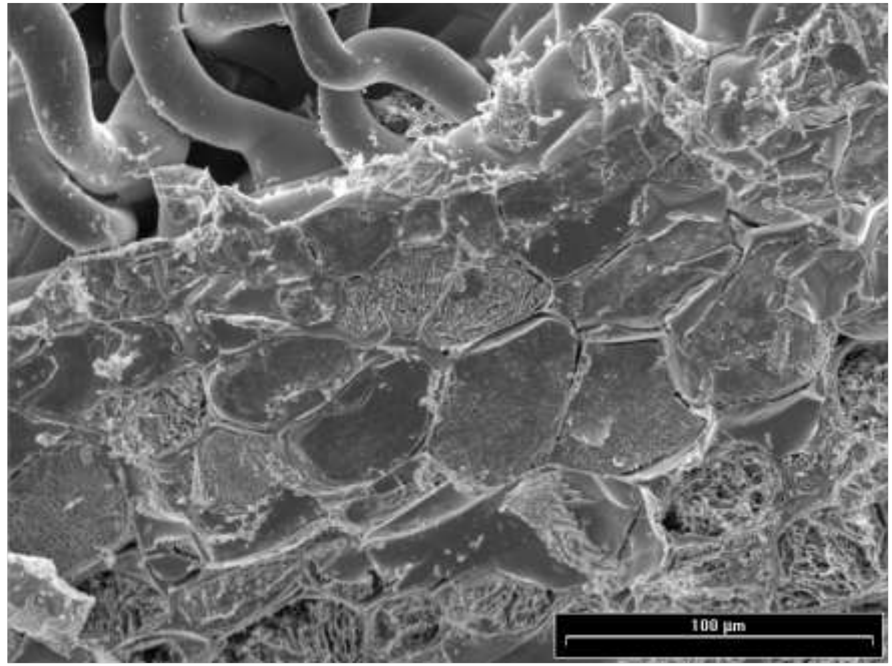


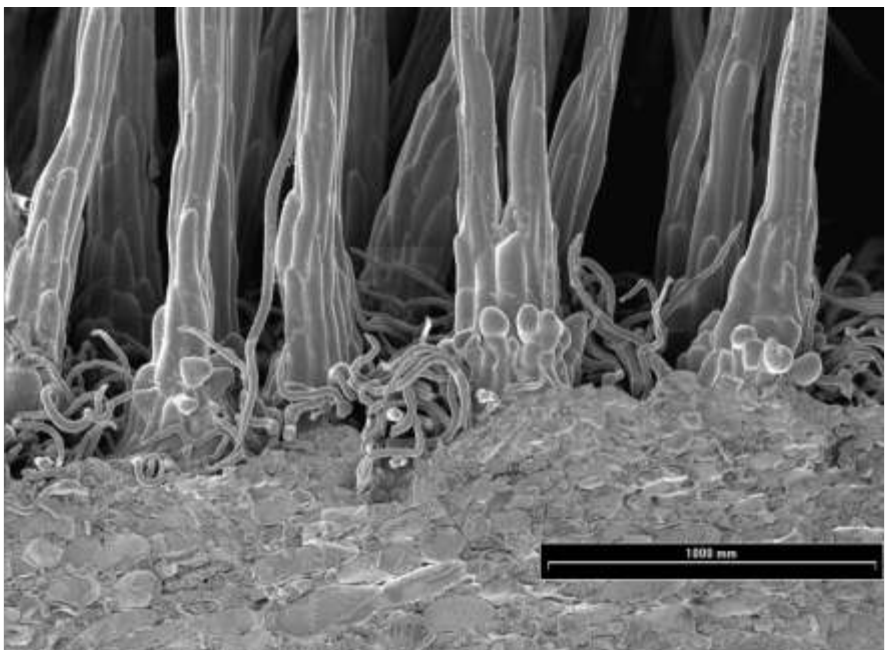
Alexander's stain method

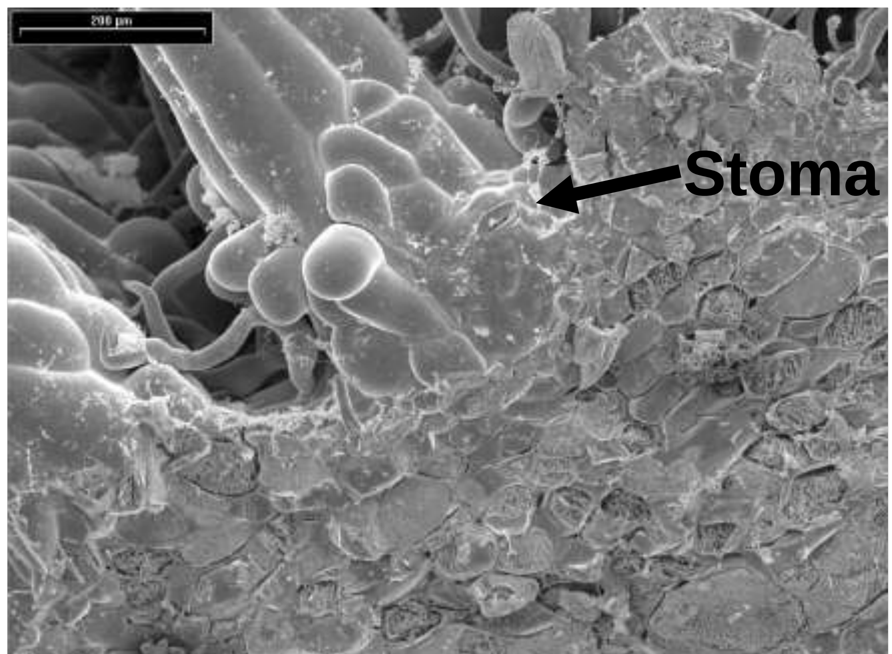
Dichio et al., 2003

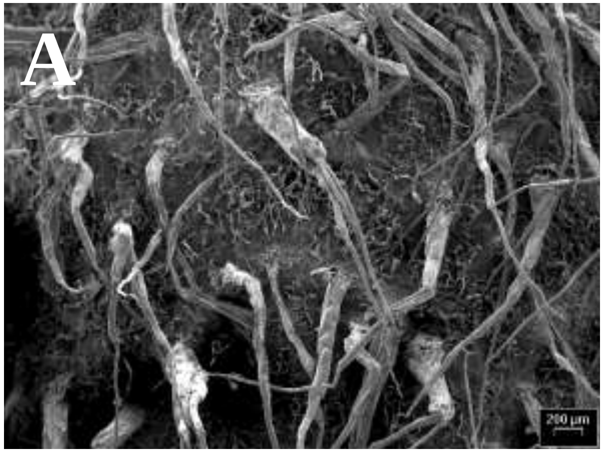


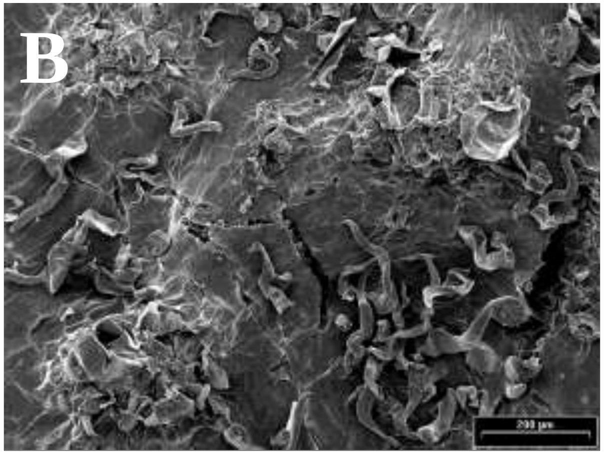
(Xiloyannis et al., 2001)





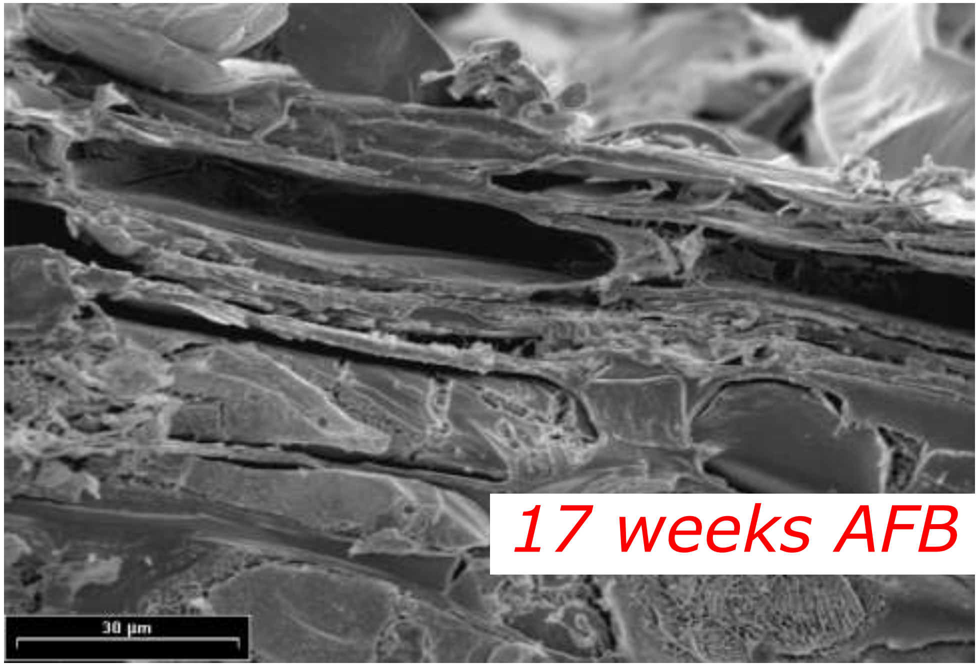






…fruit transpiration decrease with changes of:

Epidermal layer

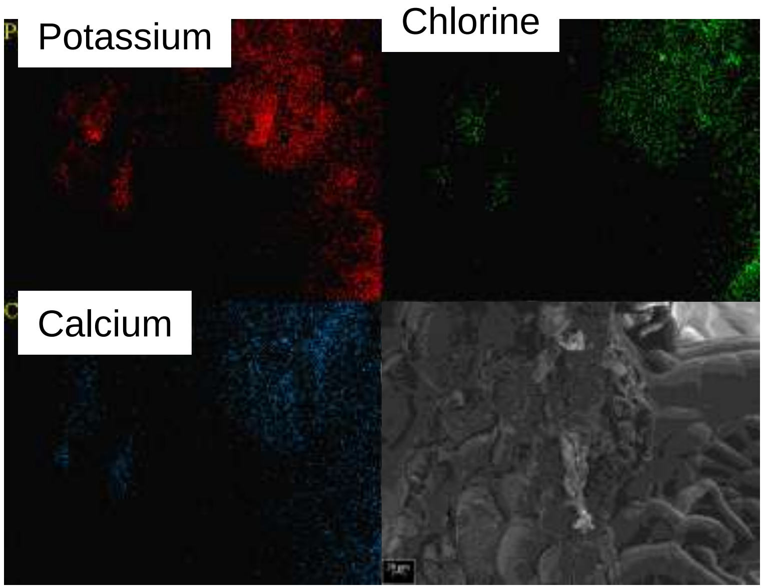


(Xiloyannis et al., 2001)

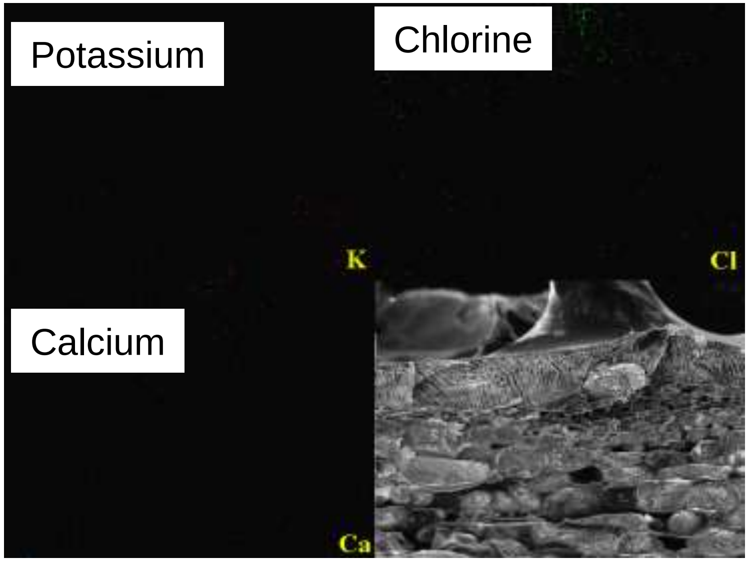
The collapse of the external layers of epidermal cells during the development of the fruit. (Xiloyannis et al., 2001).

Efficiency of sprays on fruits at different growth stages with $CaCl_2$ (0,16 M)

K, Cl, CA ions digital EDXMA map in the flesh layer of kiwifruit at different growth stage



40 days after fruit set

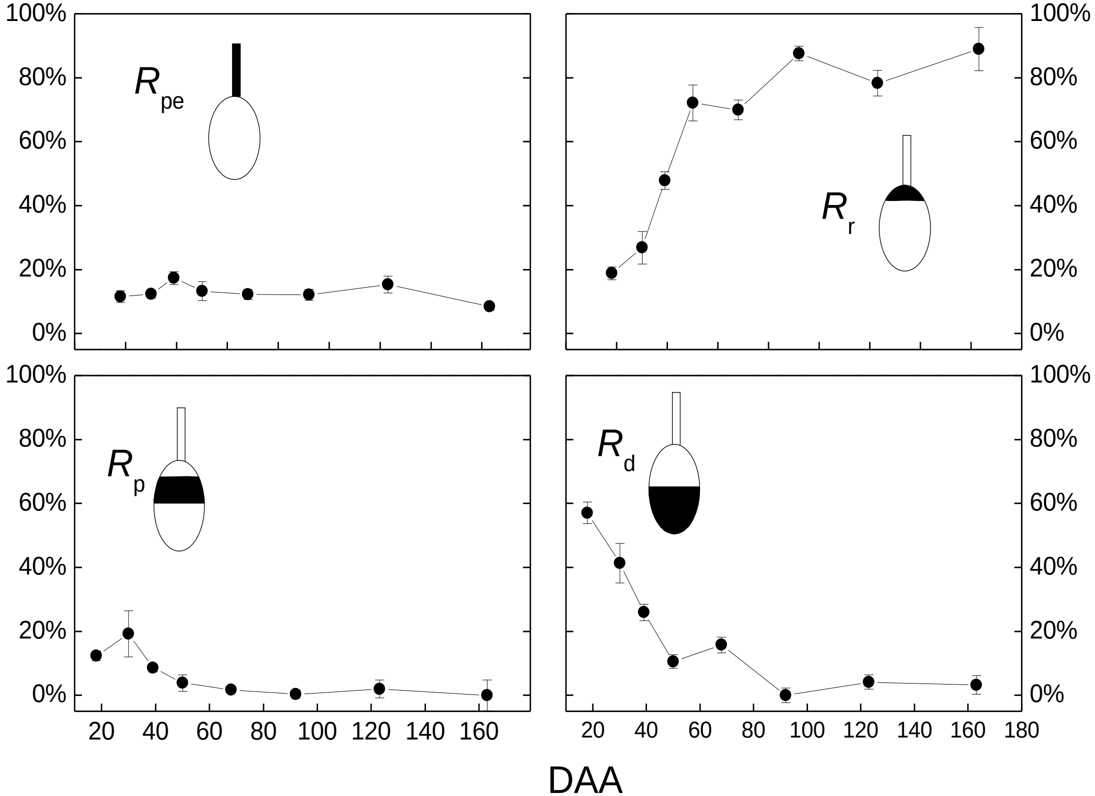


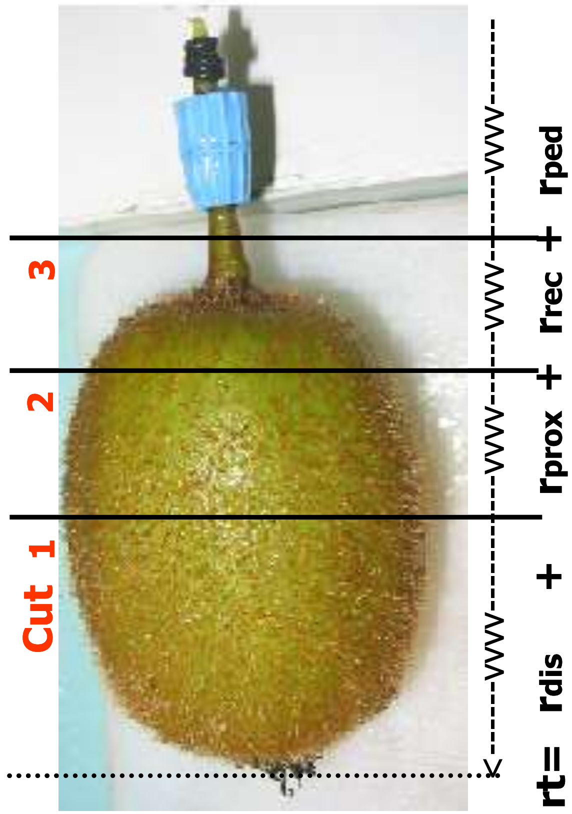
At harvest

nutrients did not reached the flesh

PHOTO Minnocci A.

…fruit transpiration decrease with changes of: Hydraulic resistances





Mazzeo et al in preparation

Hypothesis…

Radiation

Wind

Temperature

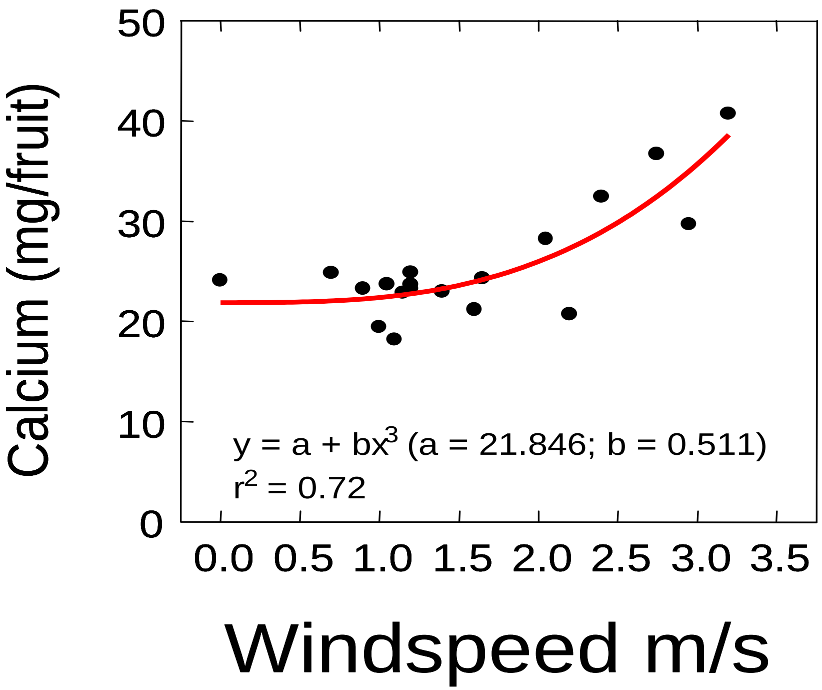
RH

→ **Transpiration** ↑ → **Xylem stream** ↑ → **Ca** ↑

How Ca naturally reach the fruit?? *A causal chain…*

Windspeed → **Transpiration**↑ → **Xylem stream**↑ → **Ca**↑

230 V electric fans in rainproof boxes created wind speeds up to 3.3 m /s



(Dichio et al. Acta Hort 2007)

How Ca naturally reach the fruit?? *A causal chain…*

Temperature, RH → **Transpiration↑** → **Xylem stream↑** → **Ca↑**

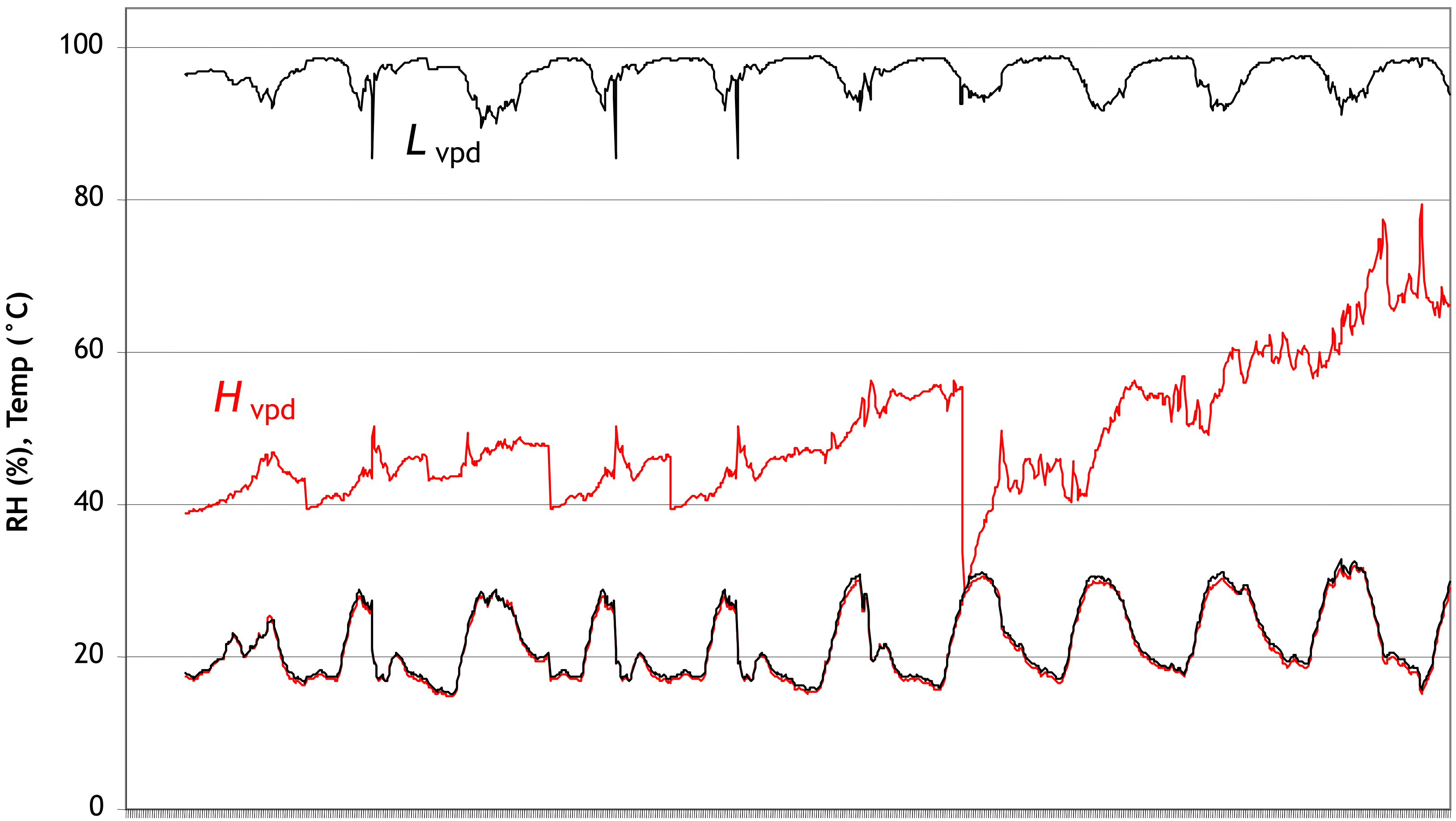
1. Control fruits

(regular transpiration)

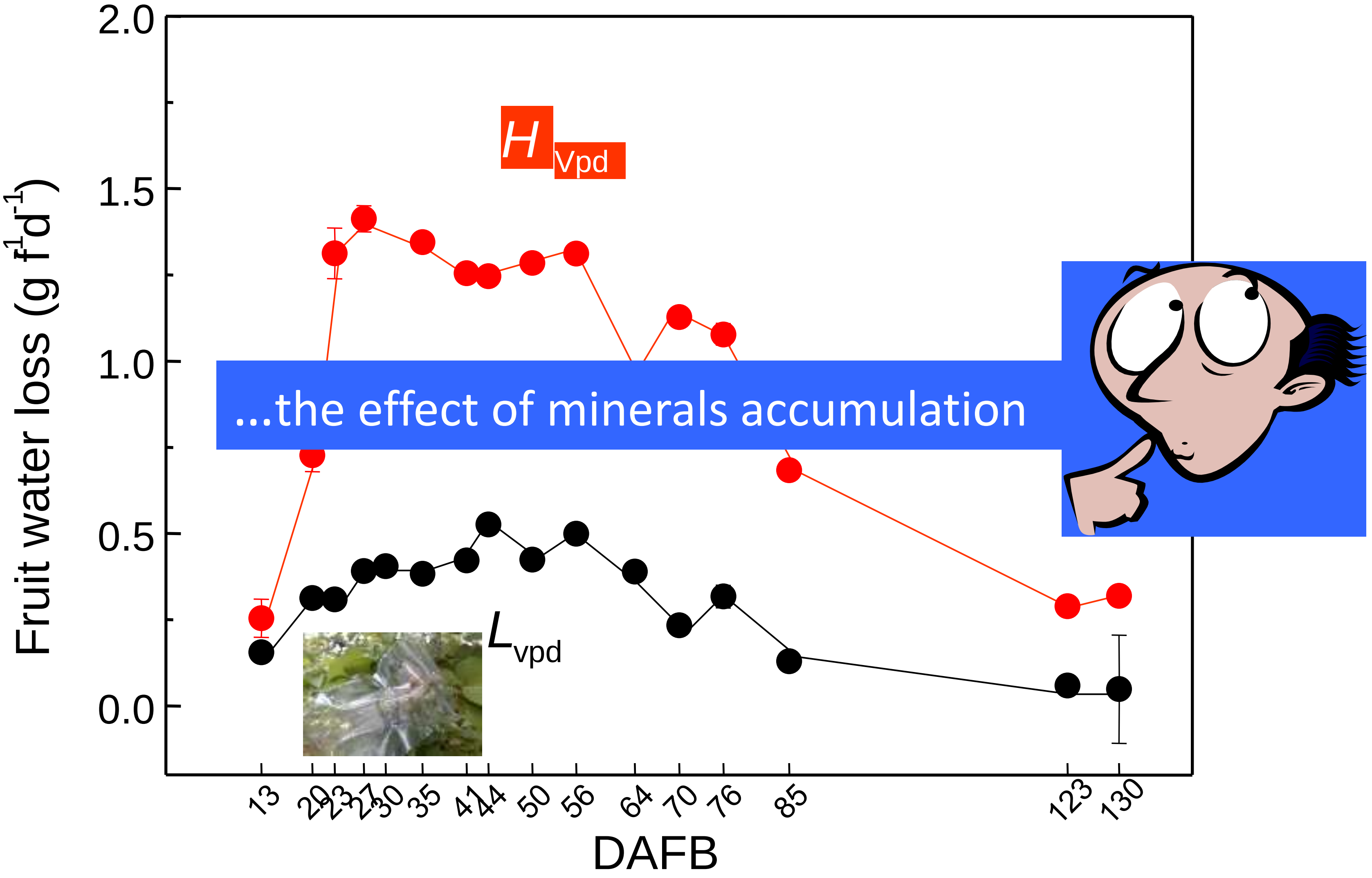
2. Bagged fruits

(restricted transpiration)

Relative humidity ~ 95% (Banuelos et al., 1987; Hofman et a



RH (%), Temp (°C)
100
80
60
40
20
0
L vpd
H vpd

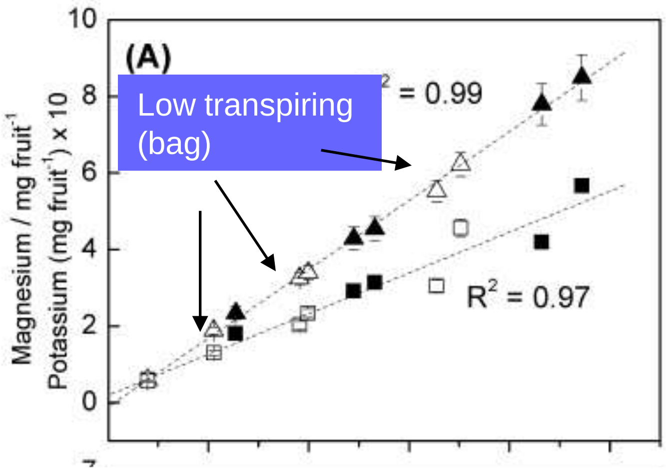


2.0
1.5
1.0
0.5
0.0
Fruit water loss (g f-1d-1)
H Vpd
L vpd
...the effect of minerals accumulation
13
20
23
27
30
35
41
44
50
56
64
70
76
85
123
130
DAFB

618 DOI: 10.1002/jpln.200900376 *J. Plant Nutr. Soil Sci.* 2010, *173*, 618–622

Significance of fruit transpiration on calcium nutrition in developing apricot fruit

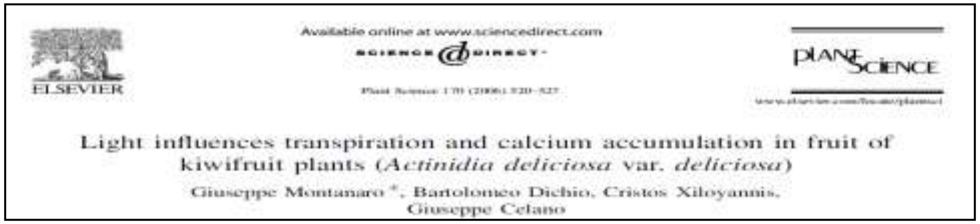
Giuseppe Montanaro[1]*, Bartolomeo Dichio[1], and Cristos Xiloyannis[1]



Dry weigh per fruit (g)

K, Mg

Xylem/phloem mobile nutrients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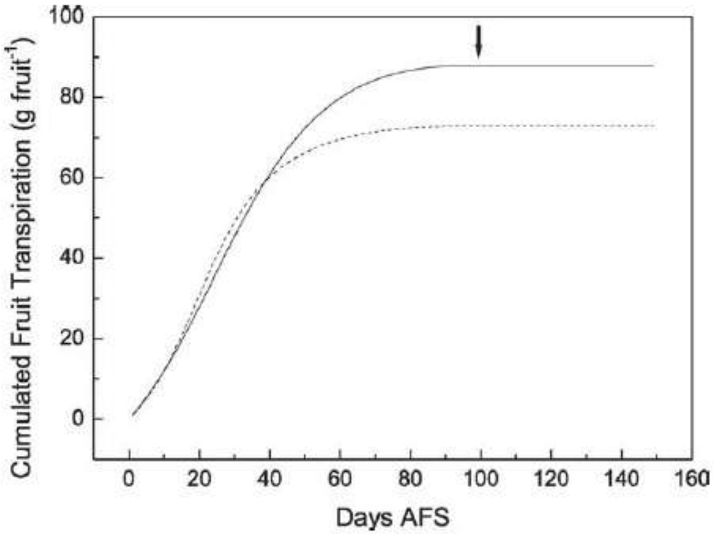
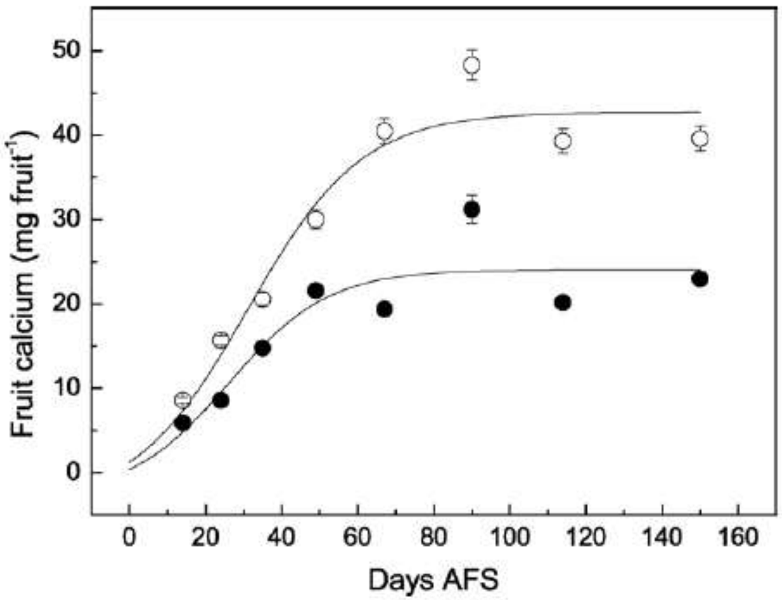
Light influences transpiration and calcium accumulation in fruit of kiwifruit plants (*Actinidia deliciosa* var. *deliciosa*)

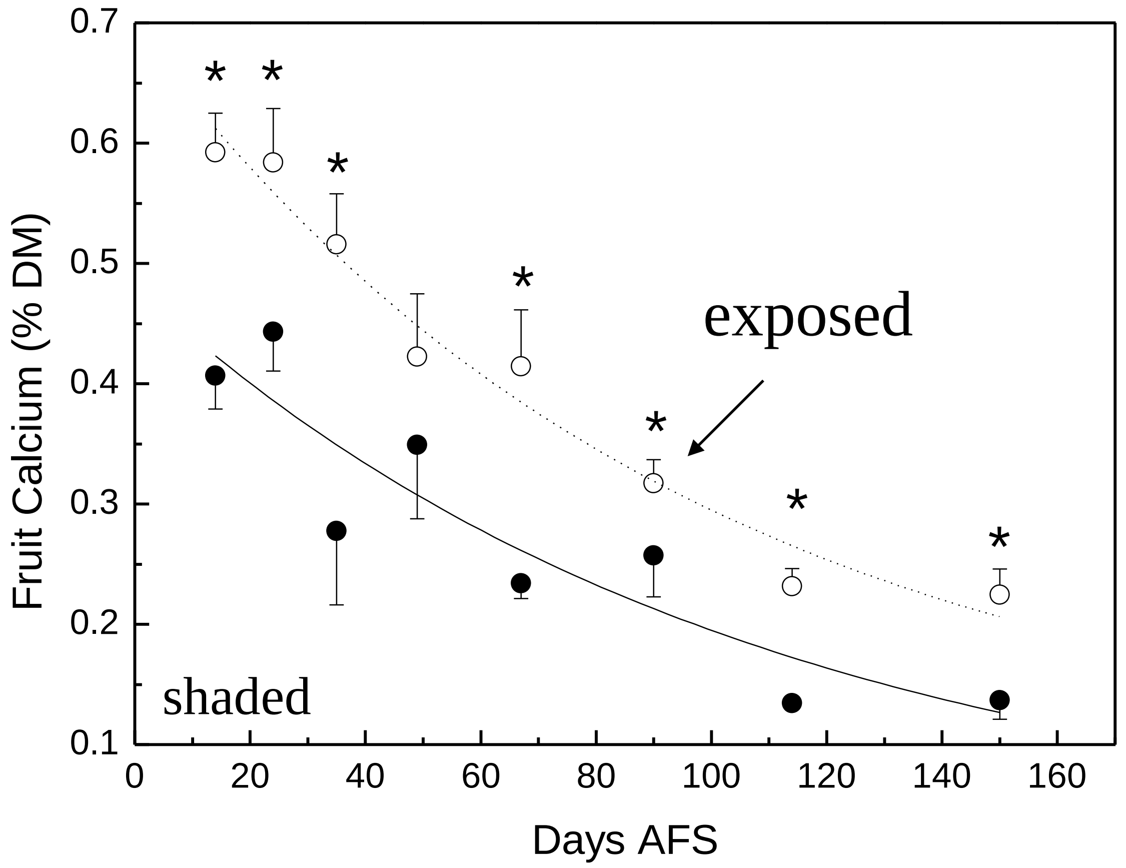
Giuseppe Montanaro *, Bartolomeo Dichio, Cristos Xiloyannis, Giuseppe Celano

Radiation → **Transpiration** ↑ → **Xylem stream** ↑ → **Ca** ↑

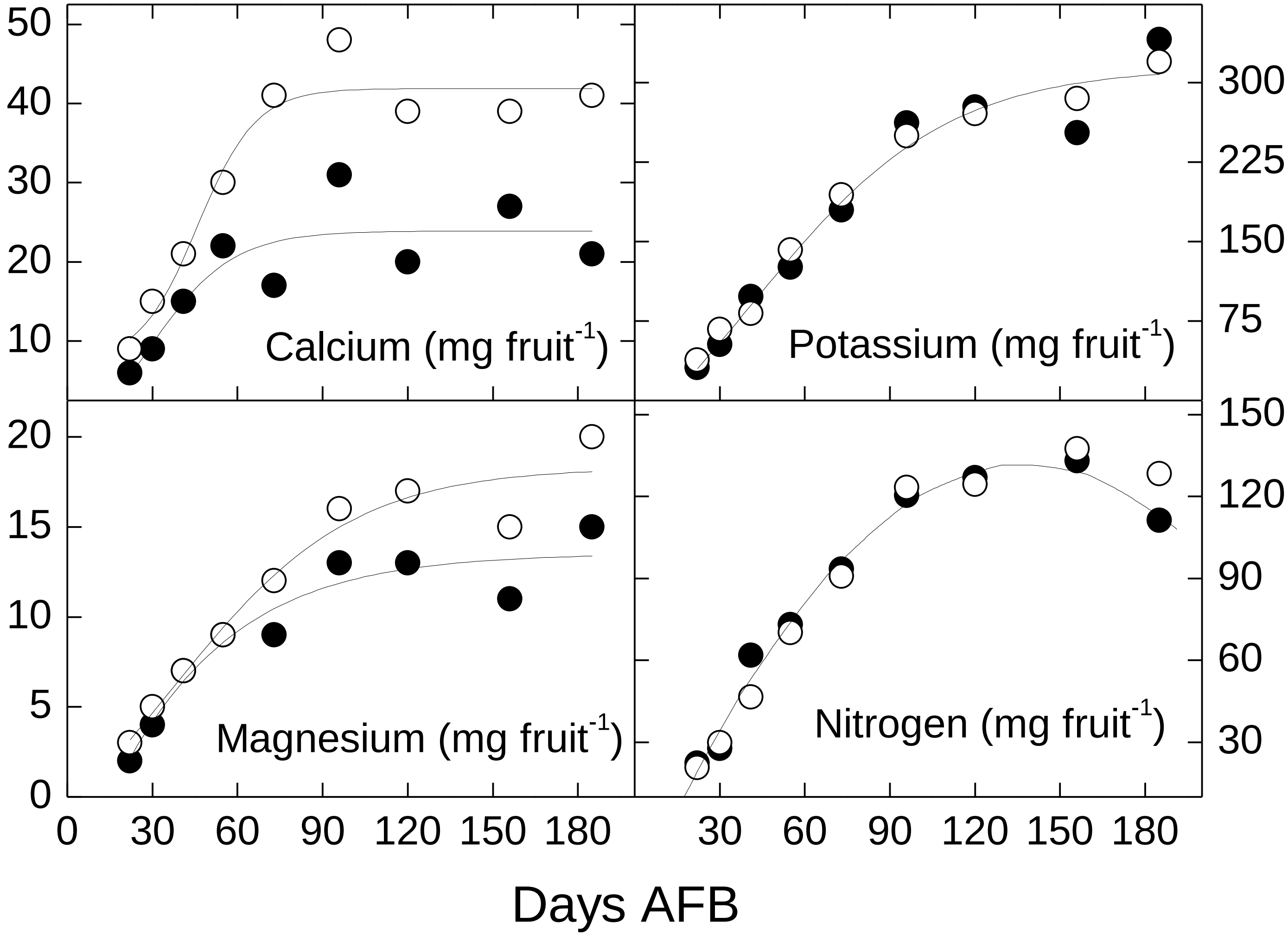


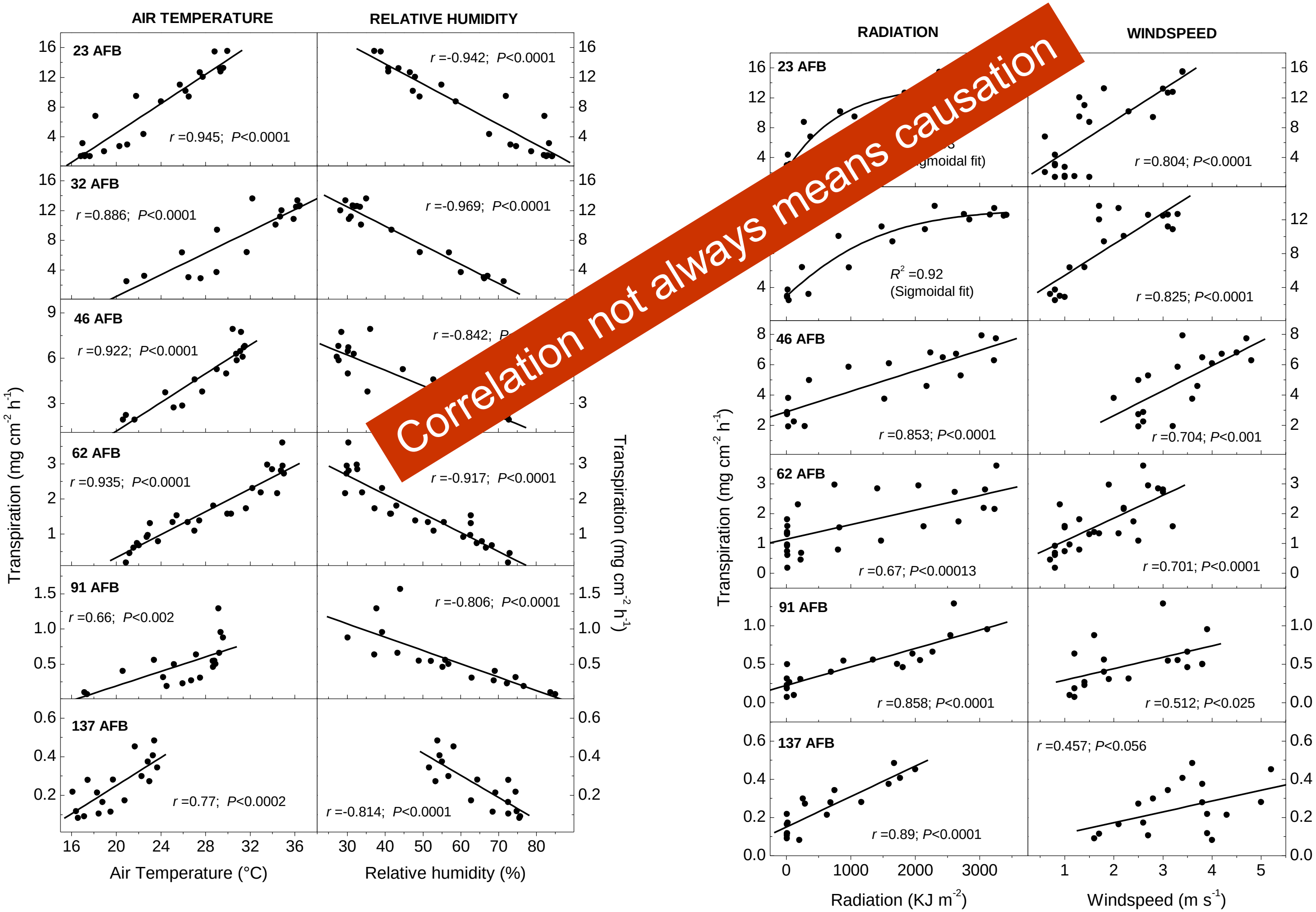


Calcium concentration in light exposed and shaded kiwifruits



Accumulo di minerali nei frutti

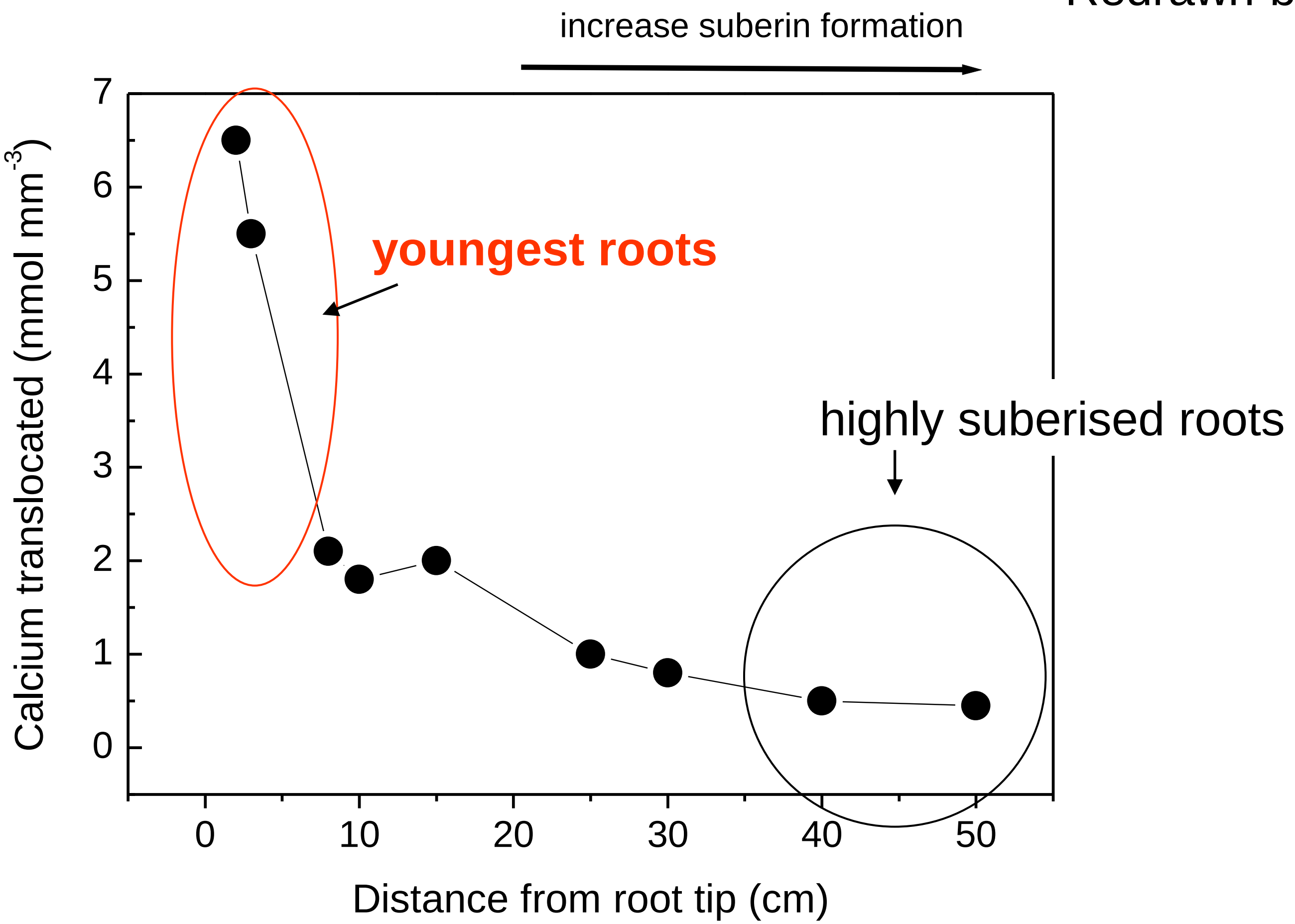




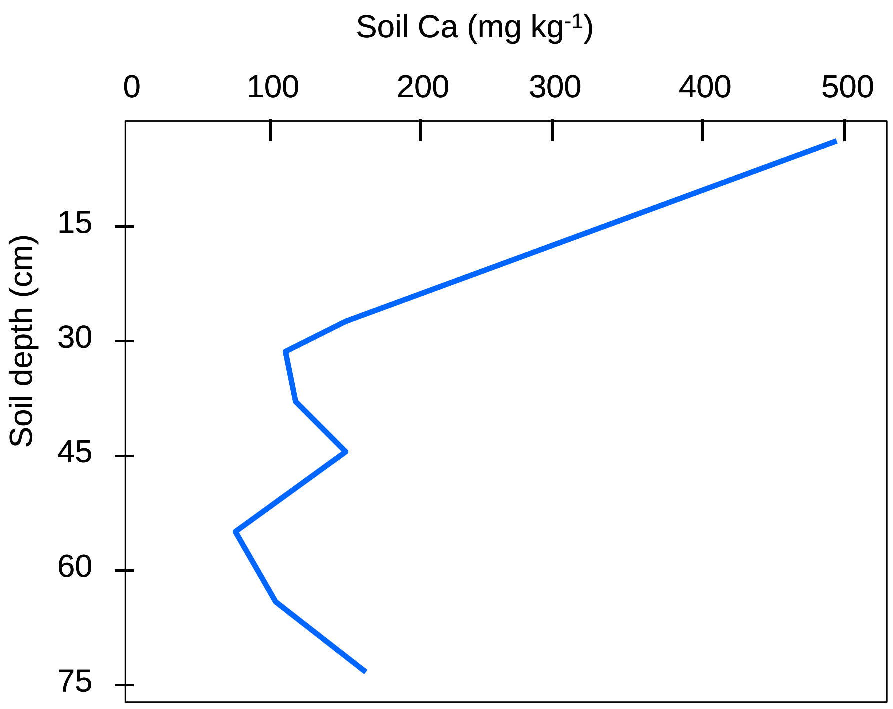
Correlation not always means causation

Youngest roots (less suberised) are more efficient

Cucurbita pepo;
Redrawn by White 2001

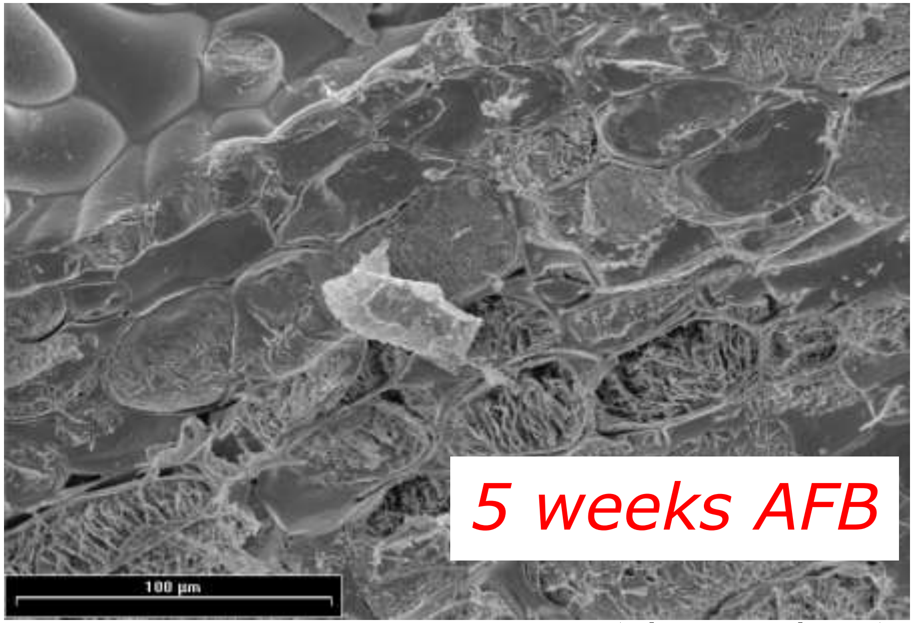


Preserving young roots at the shallow soil layers would increase Ca uptake and Ca concentration in the Xylem sap.

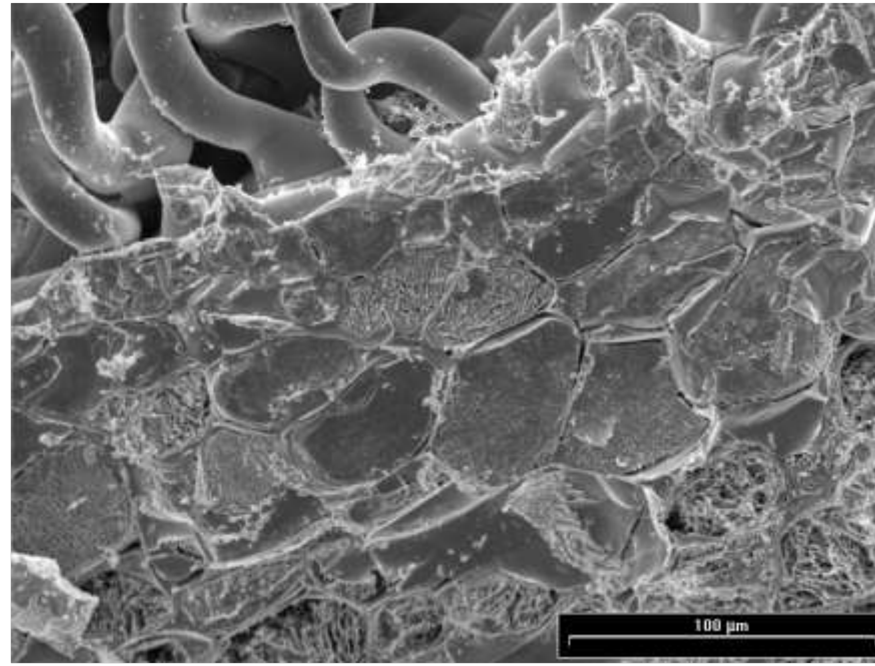


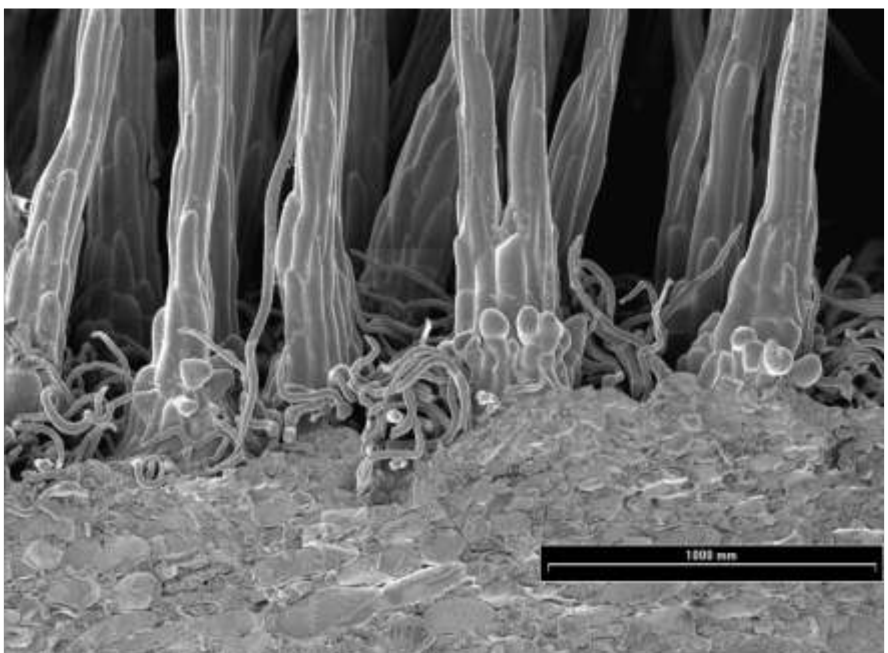
By Ortiz and Gallaher, 1985

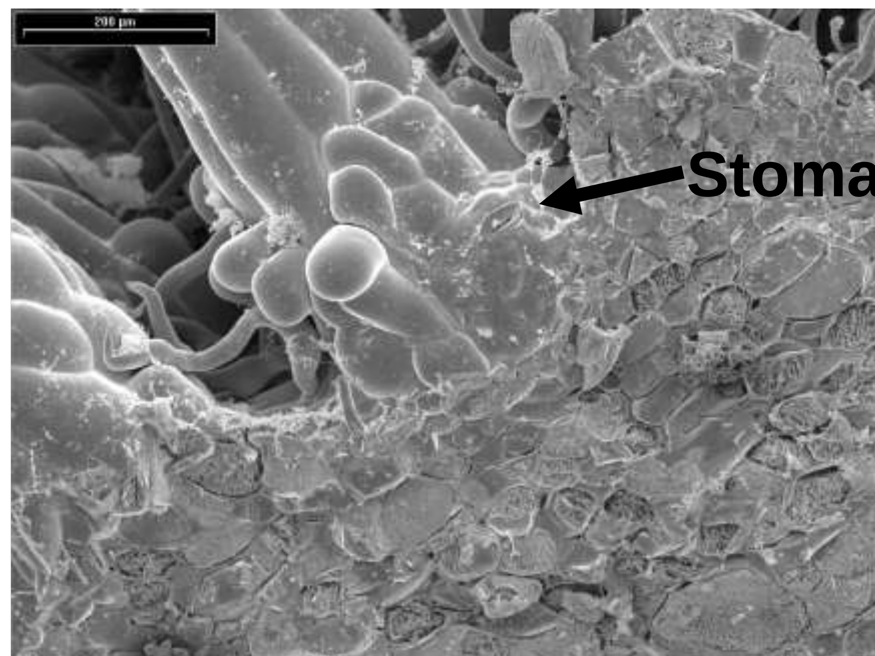
Le lavorazioni del suolo danneggiano le radici superficiali



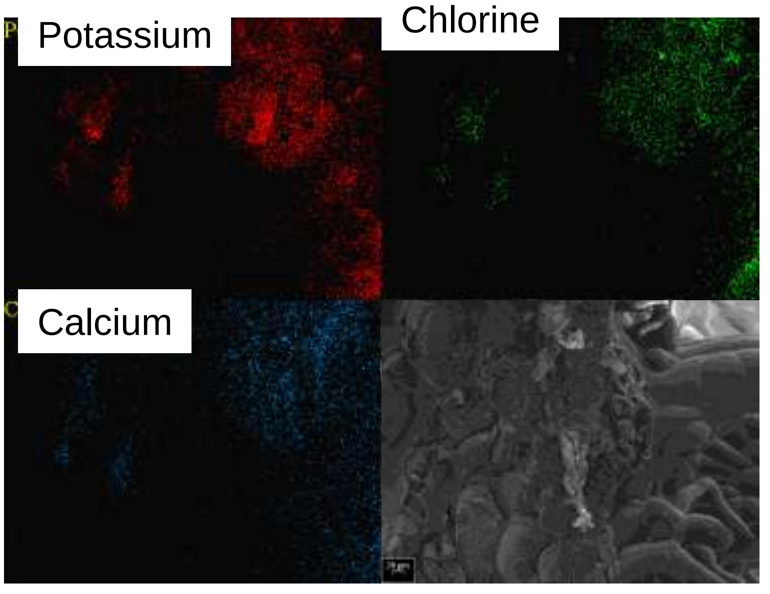
(Xiloyannis et al., 2001)





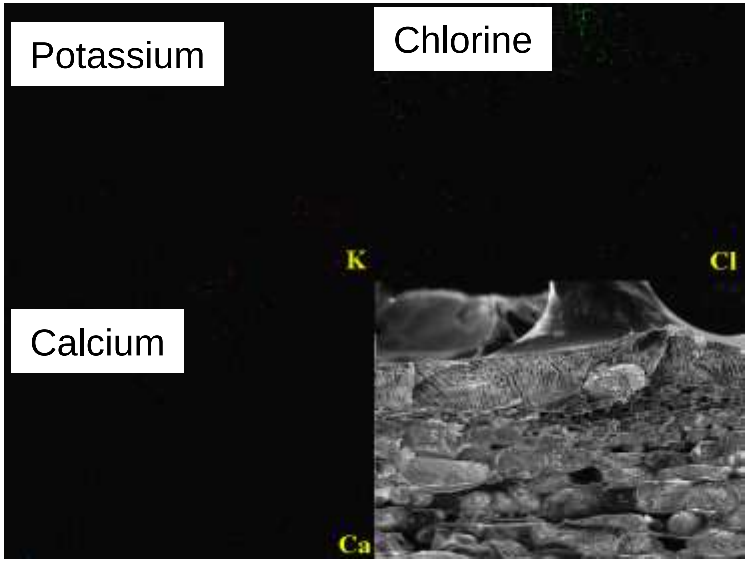


Efficiency of sprays on fruits at different growth stages with $CaCl_2$ (0,16 M)



K, Cl, CA ions digital EDXMA map in the flesh layer of kiwifruit at different growth stage

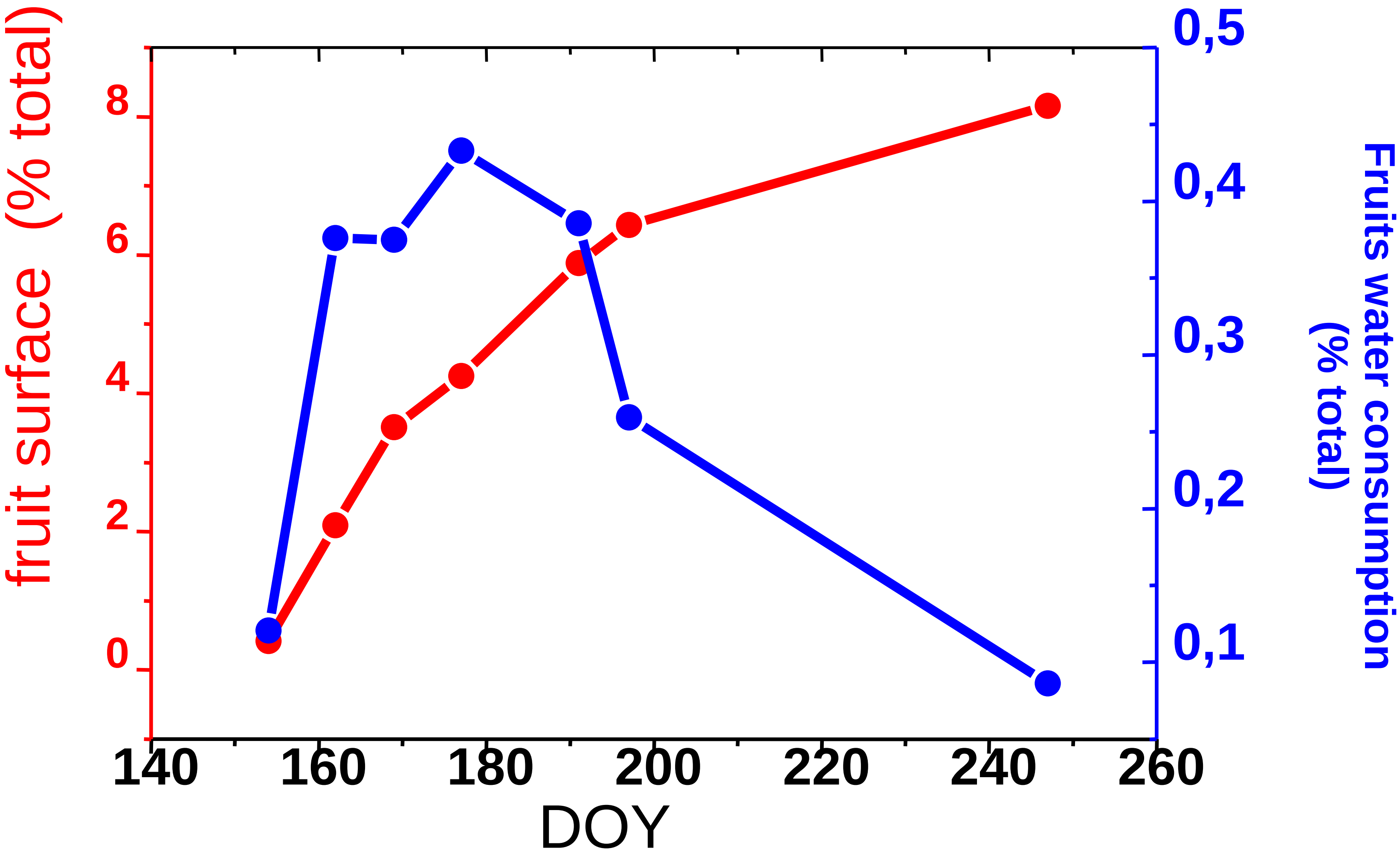
40 days after fruit set



At harvest

nutrients did not reached the flesh

PHOTO Minnocci A.


fruit surface (% total)
0
2
4
6
8
Fruits water consumption (% total)
0,1
0,2
0,3
0,4
0,5
140
160
180
200
220
240
260
DOY

→ **Ca is imported mainly within the early weeks AFS**

- **Minimize soil tillage….**
- **Reduce shoot:fruit competition…..**
- **Minimise antagonisms (e.g. K)**

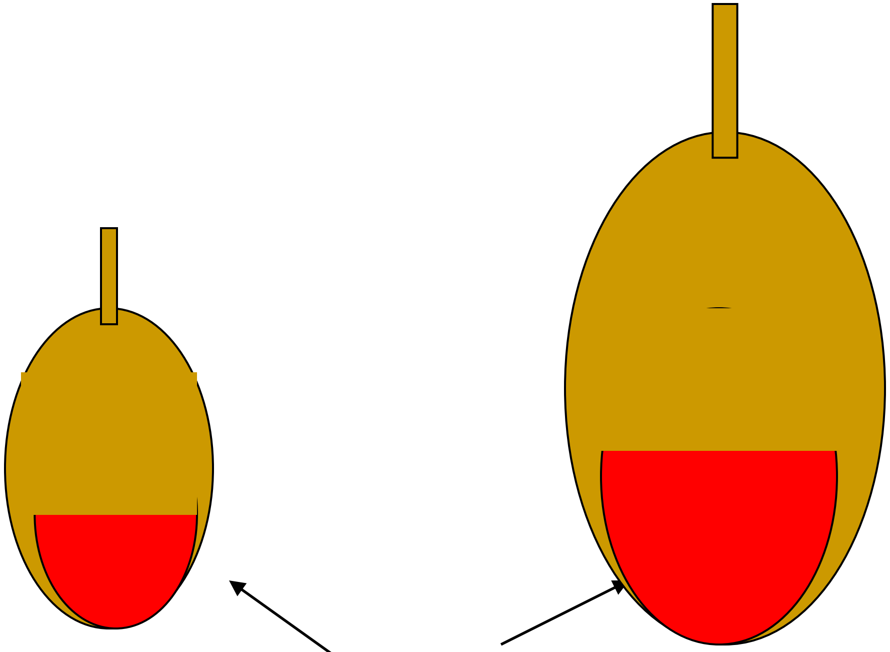
--Spray Ca no later 40-50 days AFS

--Irrigation

→ ***VPD* of the air surrounding fruit is the main driver of transpiration**

- **Training system**
- **Summer pruning**
- **Keep the grass short**

Frutti con elevata pezzatura (> 120 g) indotta con fitormoni esogeni hanno minor concentrazione in…

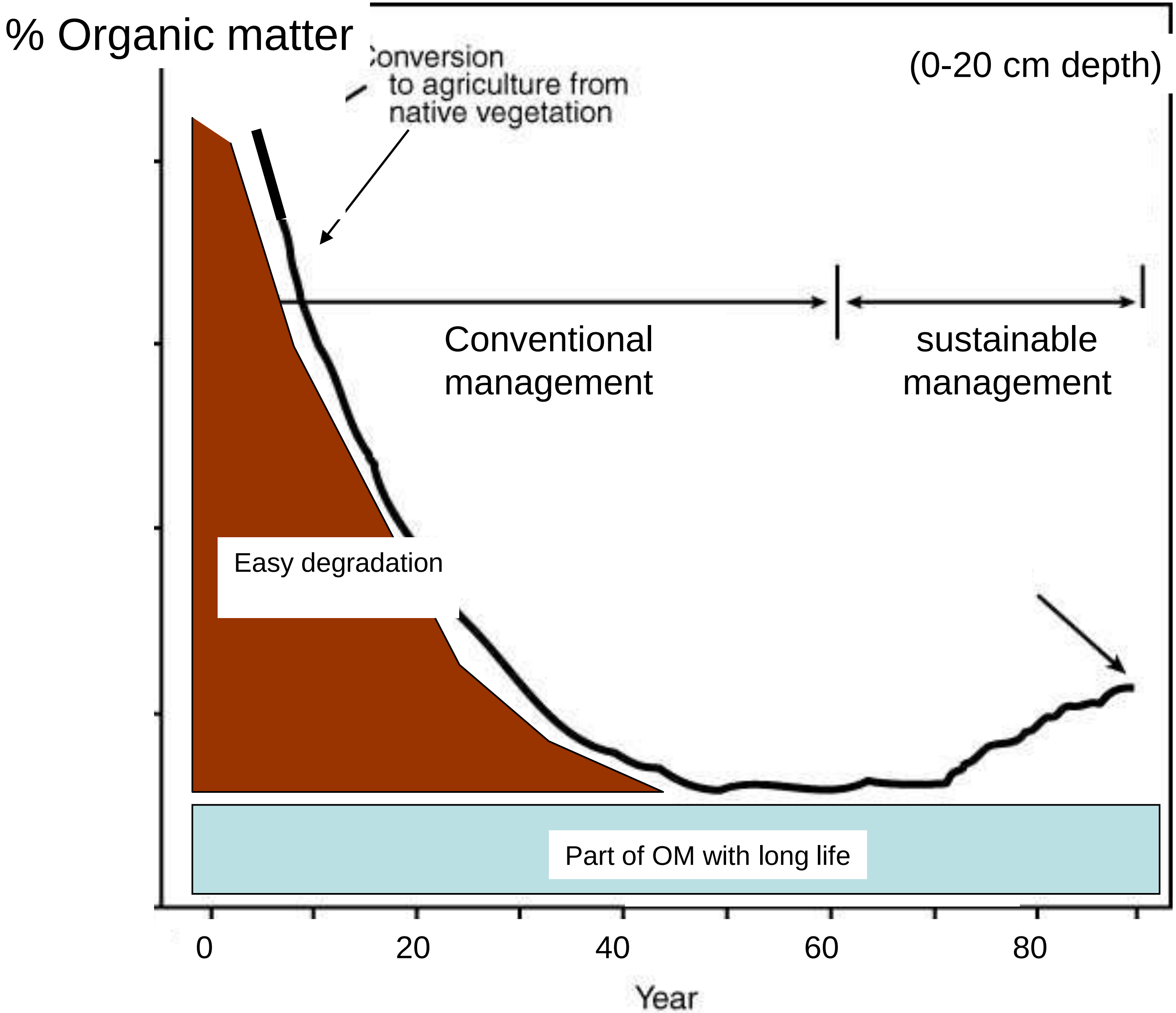


Concentrazione elementi minerali e sostanza sacca

objectives of a sustainable *fruit* orchard management

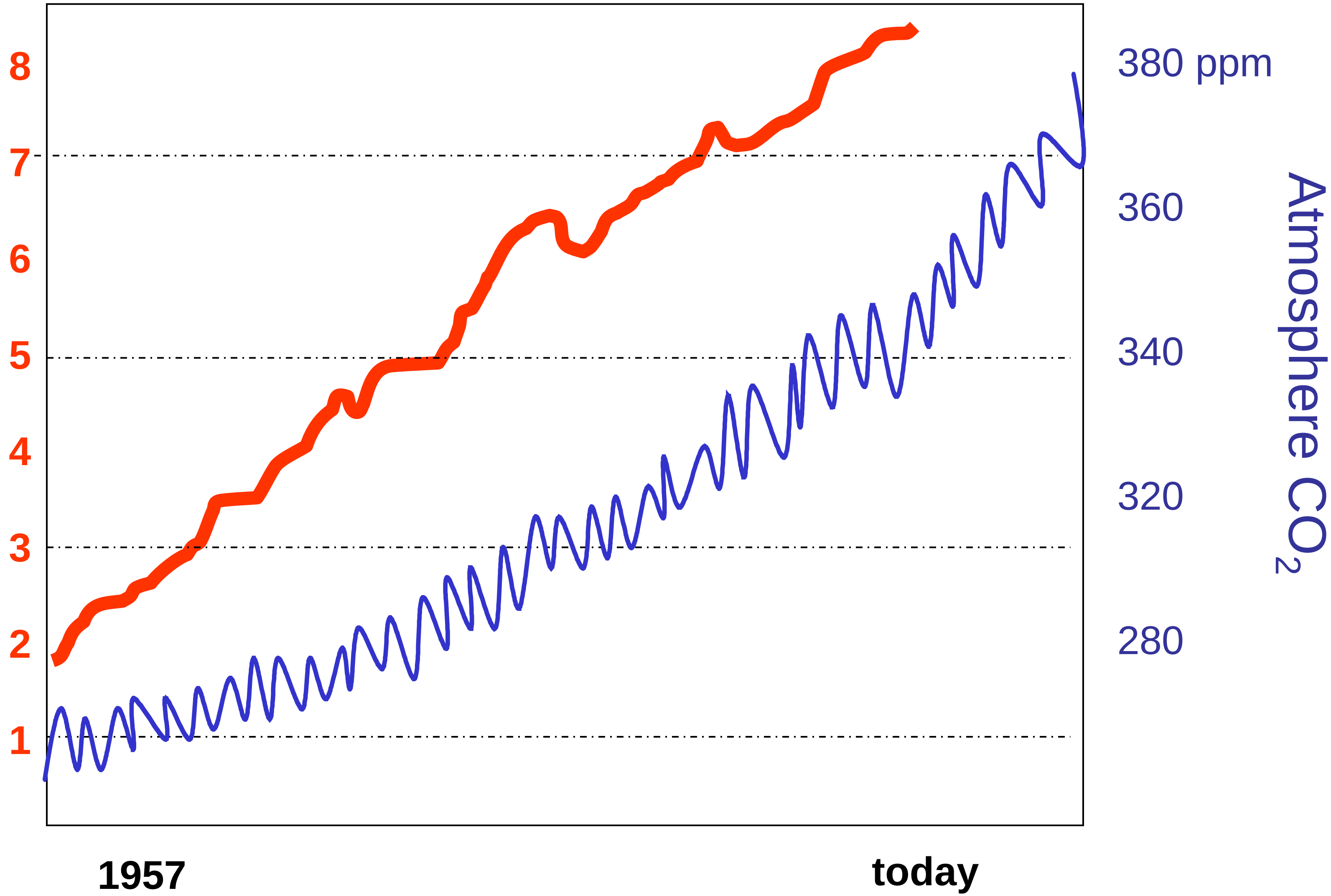
- increase and preservation of soil fertility
(= chemical, physical, microbiological quality)

by means of soil management techniques



Rielaborato da WBGU Special Report:
The Accounting of Biological Sinks and Sources Under the Kyoto Protocol

Annual global carbon emissions during the past 50 years (billions metric tons per year)



Source: National Geographic. Oct 2007 - IPCC

Total and per capita CO_2 emissions in various country

(source: UNFCCC, EEA, DIW Berlin)

	Total emissions CO_2 (Mt)		Per capita emissions (t/year)
	1990	2000 (* = 2001)	2000 (* = 2001)
Australia	259	502	26,8
Canada	421	726	24,0
USA	4844	7001	19,0
Arabia Saudita	160	271	13,1
EU 15 *	3152	4120	11,0
Sud Africa	291	354	8,5
Cina (+ Hong Kong)	2389	2893	2,3
India	595	908	0,9

Soil fertility

Organic matter in South Italy
0,8 - 1,3%

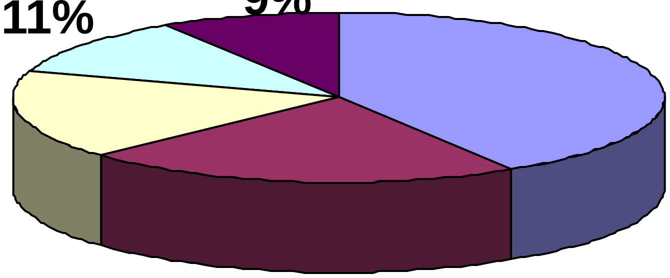

NO PULP
NO PULP
ORIGINAL
Tropicana
PURE PREMIUM
= 1,7 kilo de CO2
100%
PURE & NATURAL
ORANGE JUICE


30 kilos de CO2
66 Pounds
13 kilos de CO2
54 kilos de CO2
3 kilos de CO2
43 tonnes de CO2
97,000 Pounds
3 kilos de CO2

Partitioning of Carbon footprint for each stage of the NZ-kiwifruit lifecycle based on product shipped to Europe.

1.74 Carbon eq for every kg of fruit

UK's PAS 2050, Methodology



Source: Zespri.com

Source ZESPRI.COM

ORCHARD FACTORS:

PAS 2050:2008

Electricity

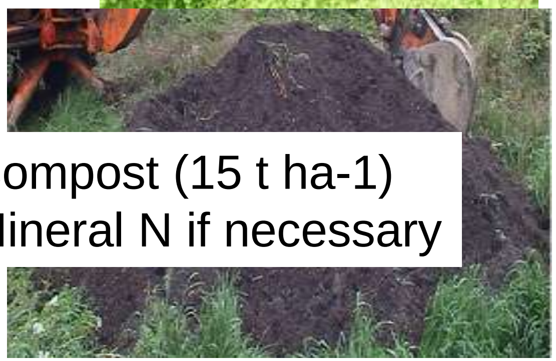
Diesel

Fertilisers and Pesticides

Lubrificant

Capital

Soil-plant-atmosphere carbon fluxes ARE NOT considered

Sustainable		Grower
	Soil management	
 Compost (15 t ha-1) Mineral N if necessary	Fertilization	Mineral fertilizers 
	Pruning material	

- increase C input
- limit C output

- increase C input

carbon sources

internal	external
cover crops	stabilised manure
pruning material	compost
senescent leaves	Biochar, others

the use of carbon sources can

provide mineral elements
for plant nutrition

improve soil C

choice

cover crops

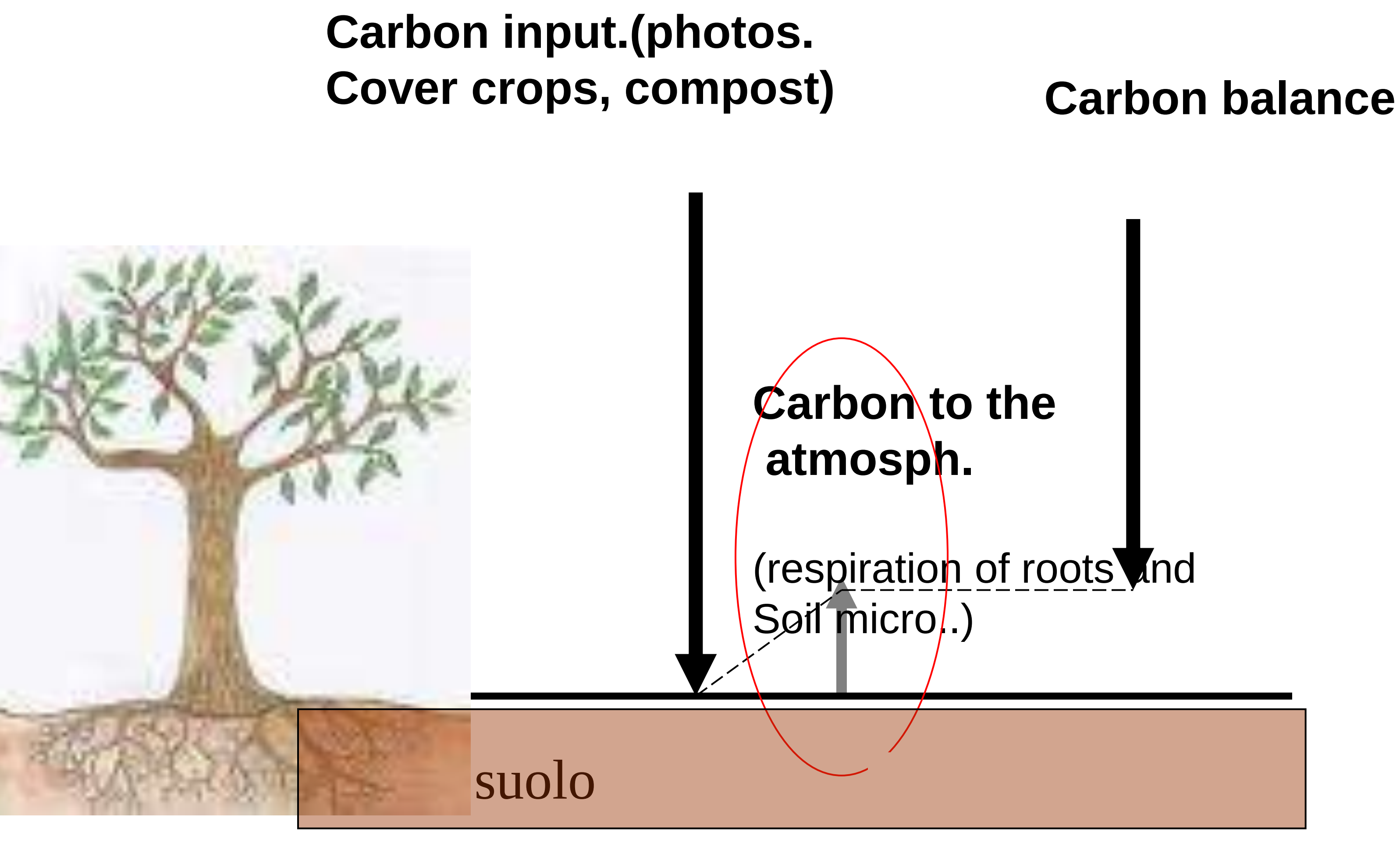
sown

spontaneous

- increase the photosynthesising surface and Root system, which extends to various depths in the soil, improves soil characteristics

- improve the C sequestration ability of the system

Carbon balance



Soil-plant-atmosphere carbon fluxes ASSESMENT

- **SEQUESTRATION** (Photosynthesis CO_2 sequestered)

+ **EMISSIONS** (soil-chamber based measurements)

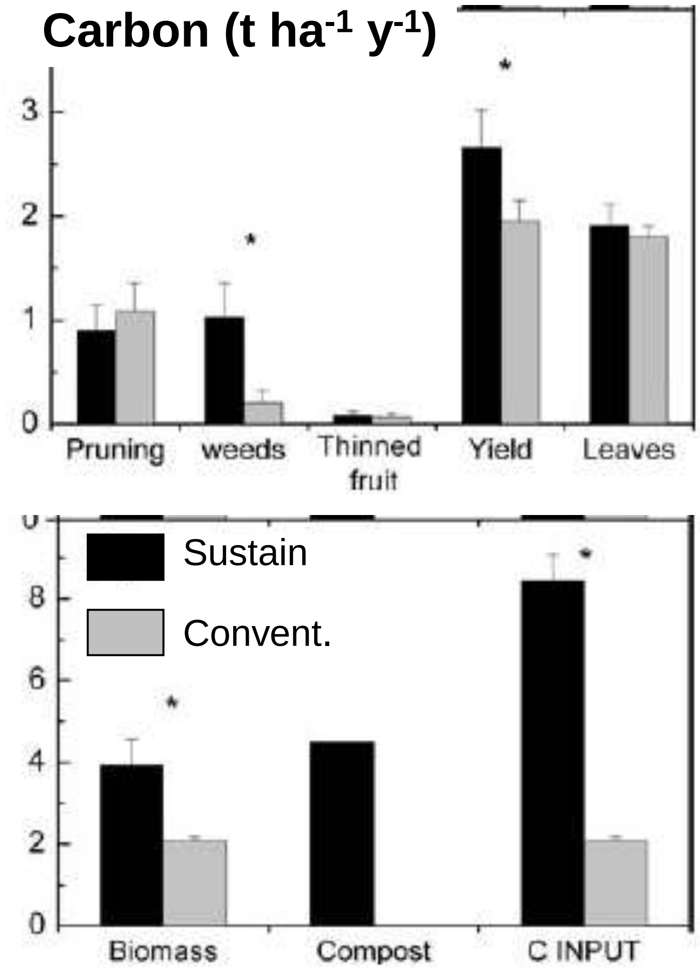
Can grower's orchard management effect CF?

Improving soil carbon storage through friendly soil practices.

-Recycling – cover crops- biomass formation

-compost application

By building soil carbon, soils also enhance water retention properties, fertility, yield and quality

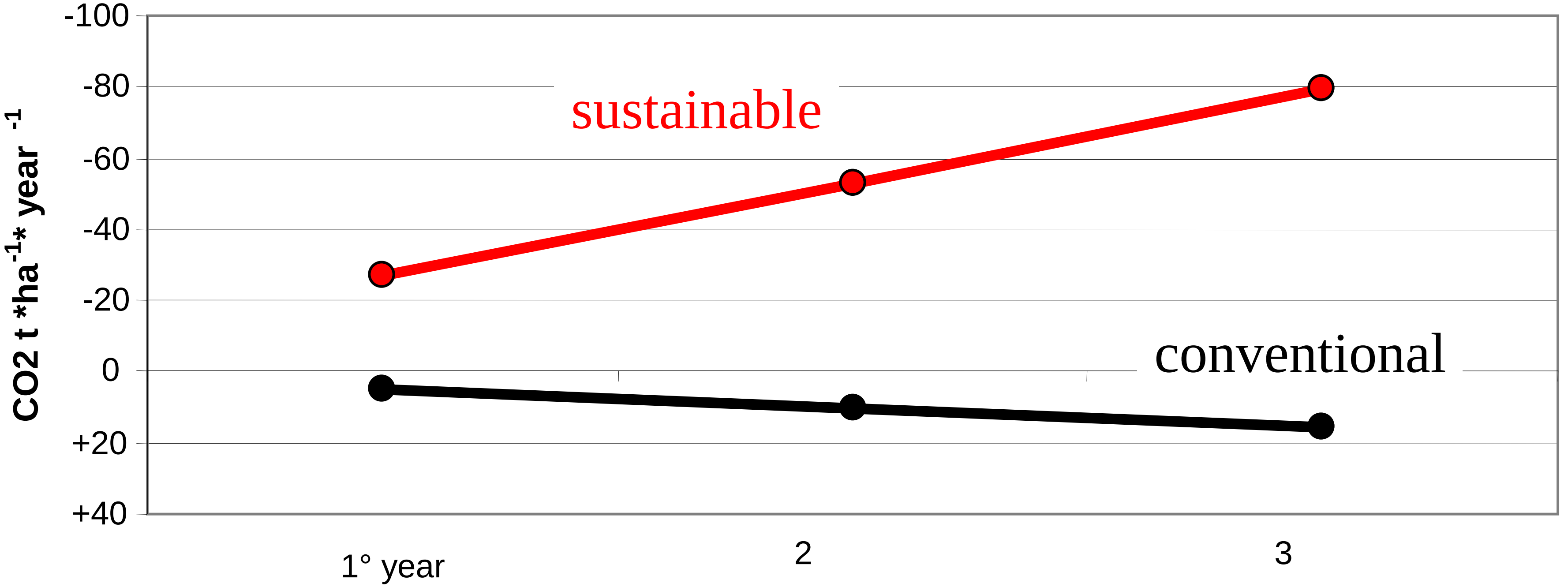


Burning residuals

or mulched *in situ*

Montanaro et al., 2010 LDD

CO_2 balance in the two systems



Sustainable in the orchard: -0.8 kg of CO^2 per kg of fruit
Conventional in the orchard:+0.26 kg of CO^2 per kg of fruit

Carbon stored in above/below-ground structures of kiwifruit vine after approx. 20 years

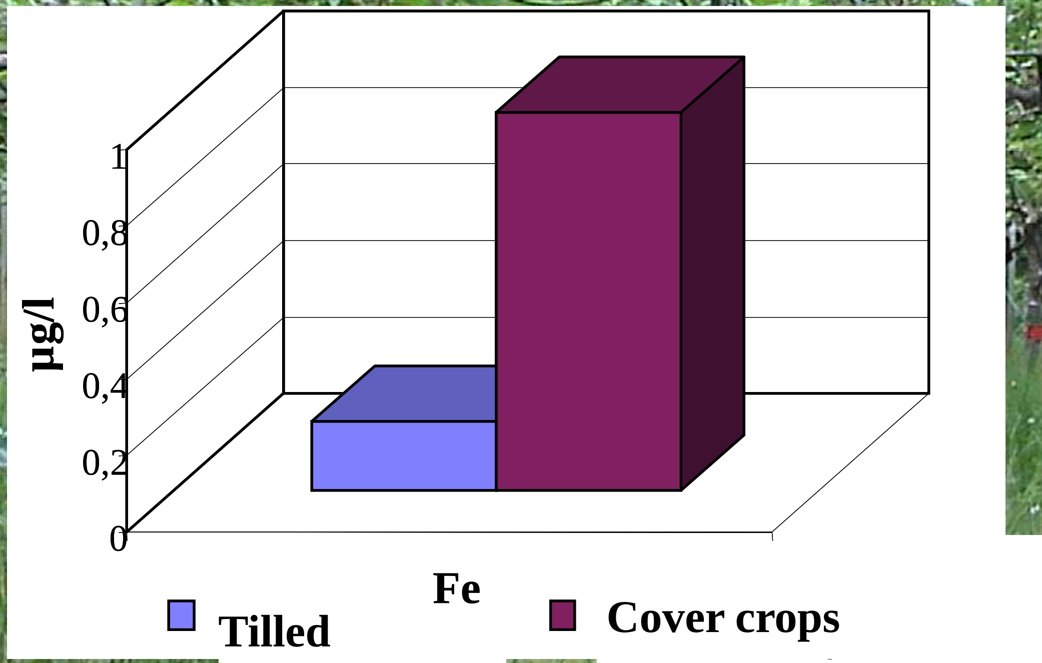
0.48 kg $vine^{-1}$ → 39.5 kg $vine^{-1}$

(1-year old) (23-year old)

~ 39 kg Δ C
(19.5 t ha^{-1}C ; 500 p/ha)

(Bouwalda and Smith, 1987) (Xiloyannis, in preparation)

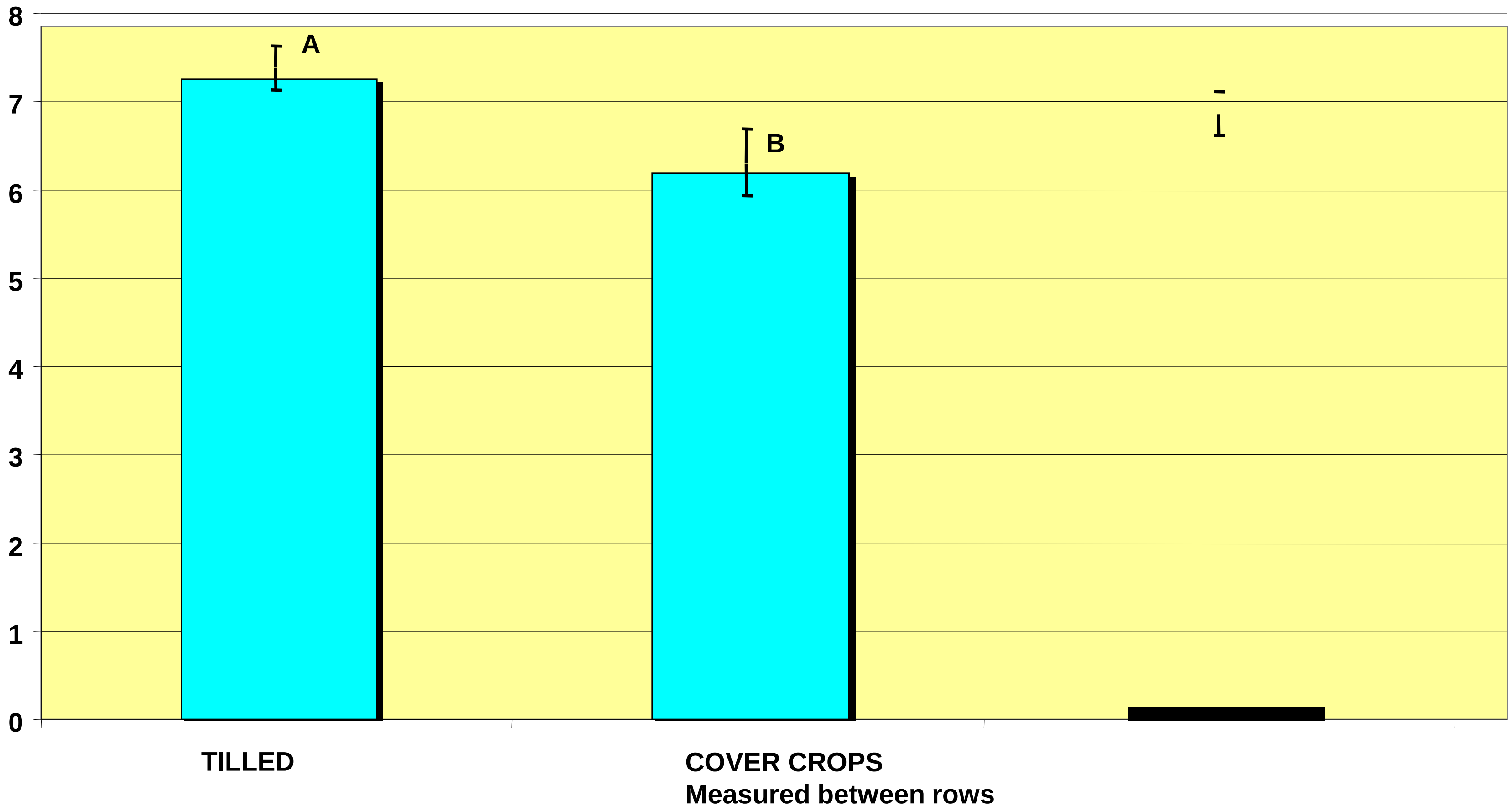
Association of some cover crops increases soil iron availability



Festuca rubra c.
Lolium perenne
Poa pratensis

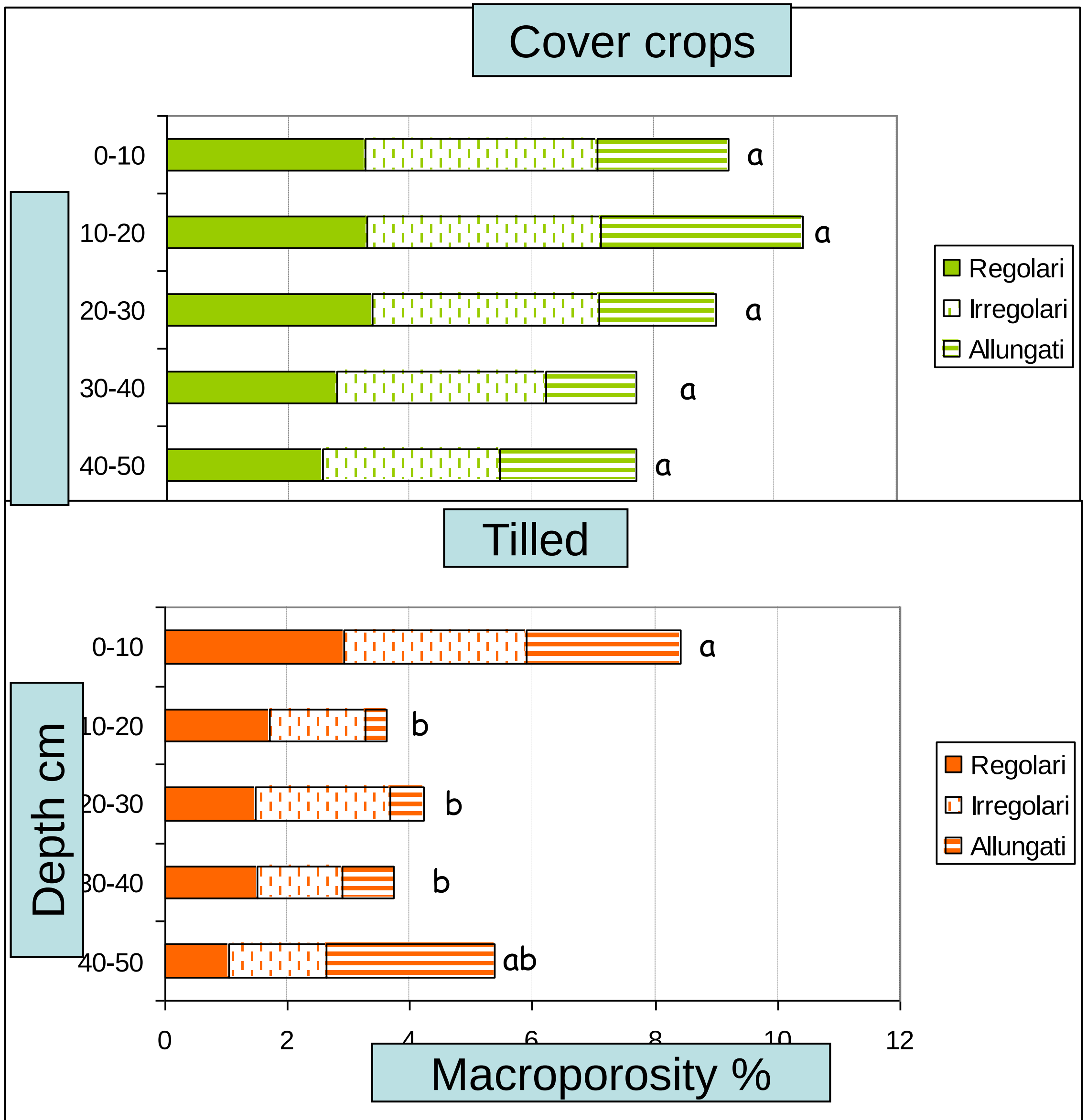
(Source: Rombolà et al.)

pH Changes after 10 years of different soil management

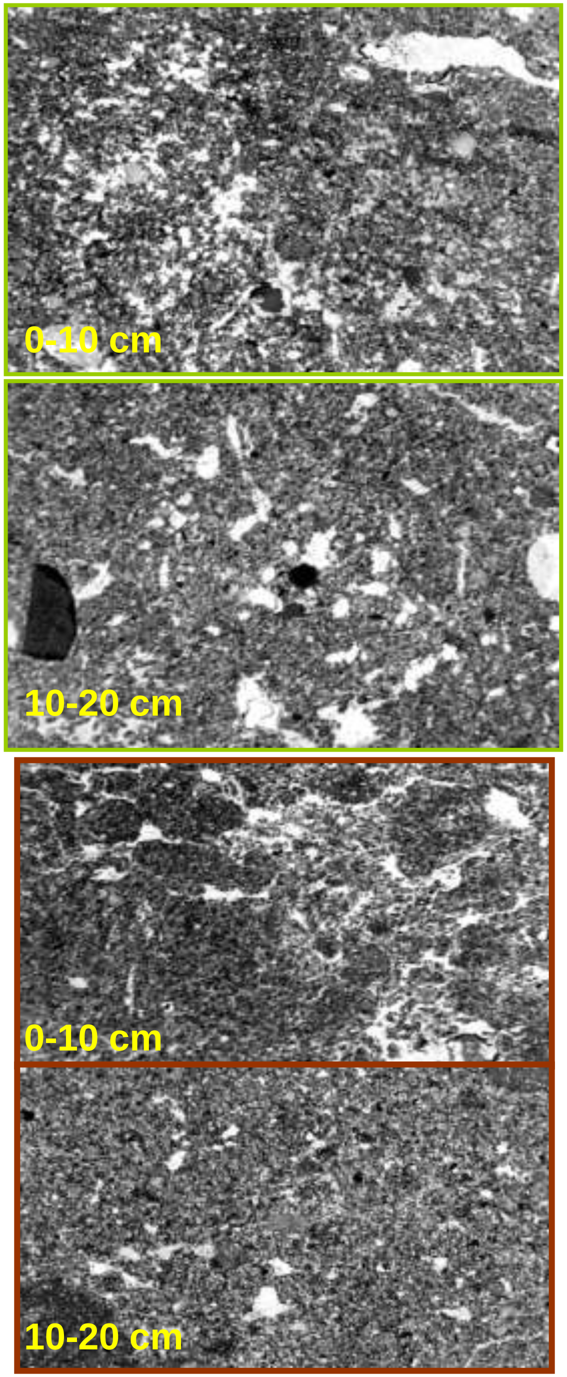


SUSTAINABLE SOIL MANAGEMENT AND

soil water holding capacity



Cover crops
0-10
10-20
20-30
30-40
40-50
a
a
a
a
a
Regolari
Irregolari
Allungati
Tilled
0-10
10-20
20-30
30-40
40-50
a
b
b
b
ab
Regolari
Irregolari
Allungati
Depth cm
0
2
4
6
8
10
12
Macroporosity %



0-10 cm
10-20 cm
0-10 cm
10-20 cm

Saturated hydraulic conductivity measurements

(Model 2800 Guelph Permeameter, Santa Barbara, USA)

Evaluation of the vertical water flux (using a plastic tube as confined well)

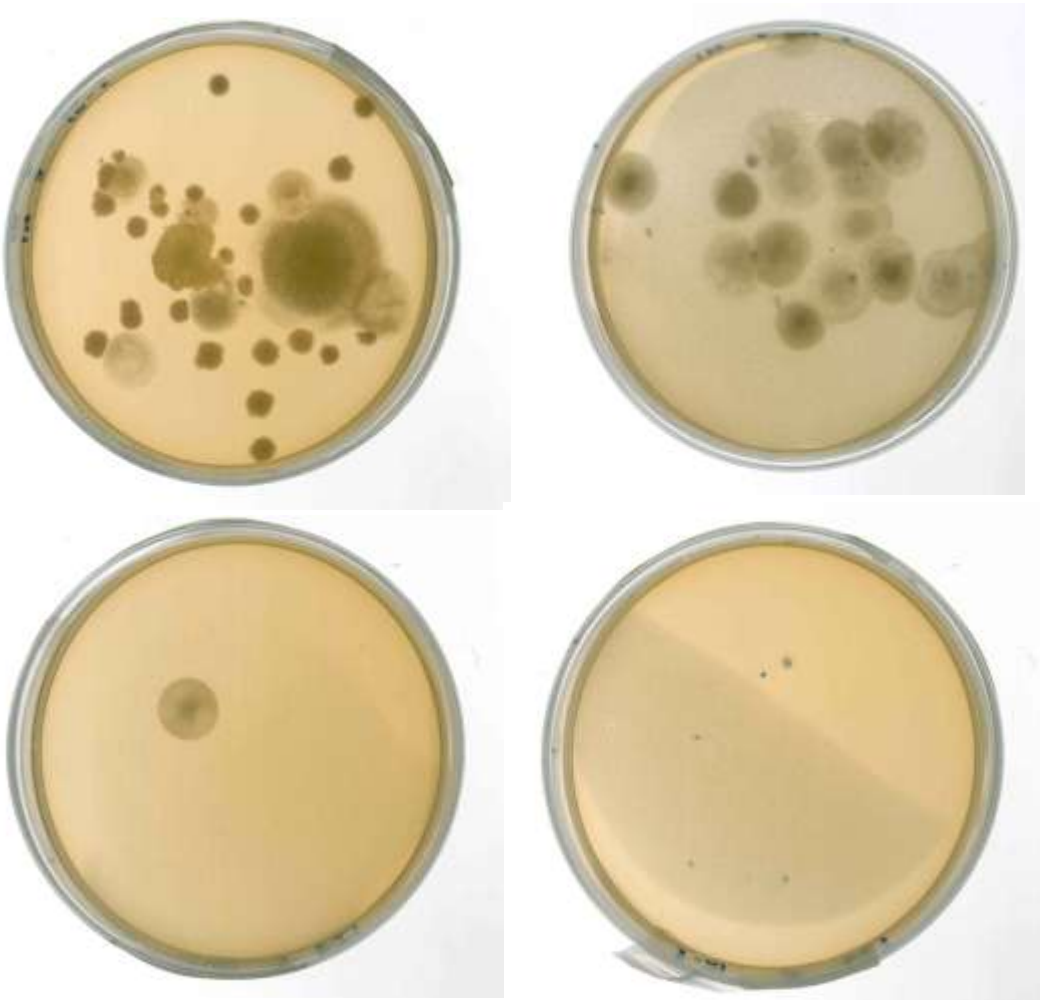
Soil Water Conducibility

Treatments	K_{sat} (Guelph) (mm d^{-1})	
Sustainable	160	
Conventional	13	

most rappresentative genus of fungi in the two systems (some of them produce glomalin)

Sustainable	Conventional
Aspergillus	*Aspergillus*
Streptomices	*Mucor*
Phaeoacremonium	
Penicillium	
Armillaria	
Cladosporium	*Rosellinia*
	Mucor
Acremonium	Cladosporium
Alternaria	
Phaeoacremonium	
Rosellinia	
Phyalophora	
Cylindrocarpon	
Microdochium	

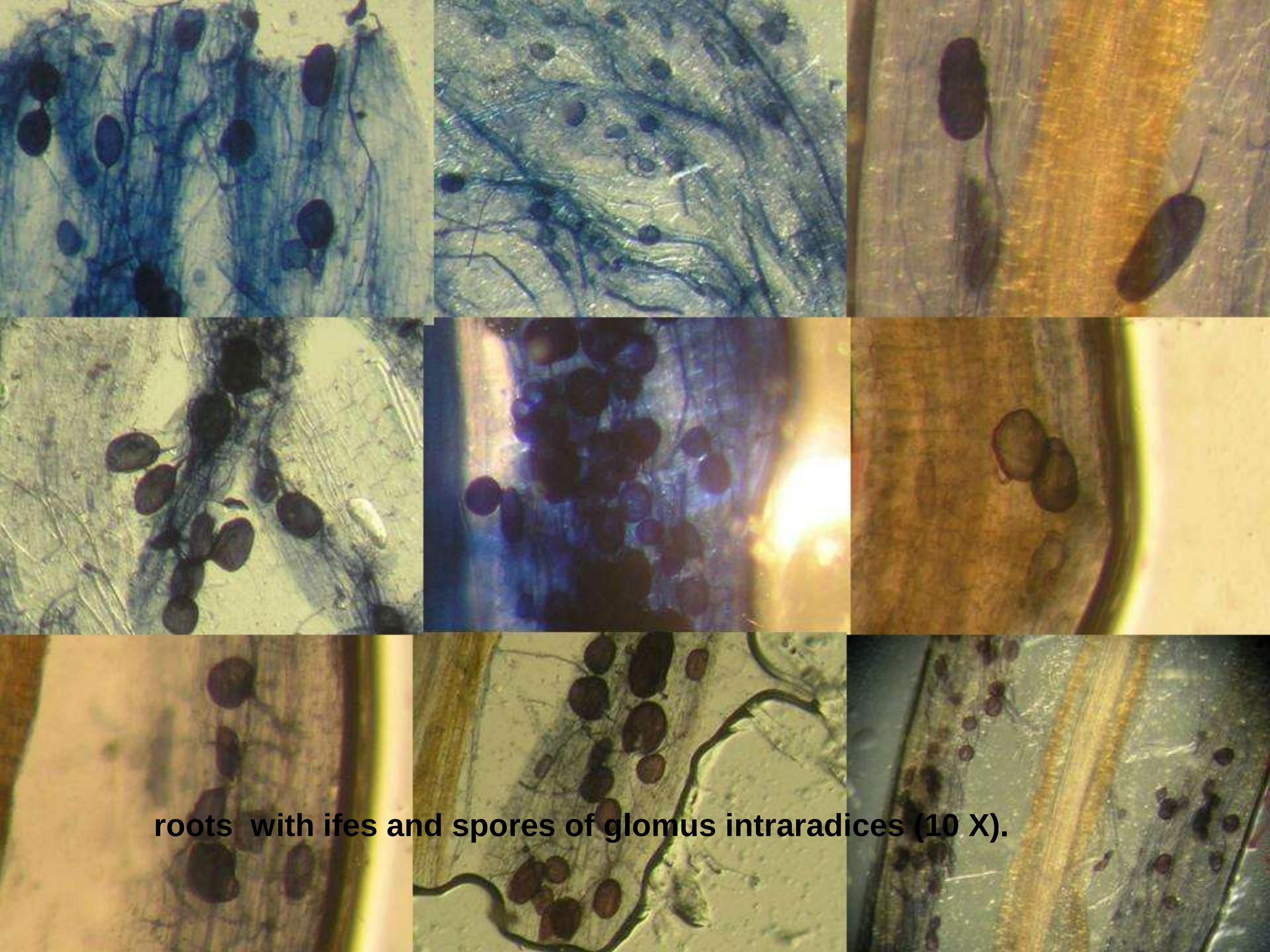
More funghi in the soil of sustainable system (diluition 10^{-2})



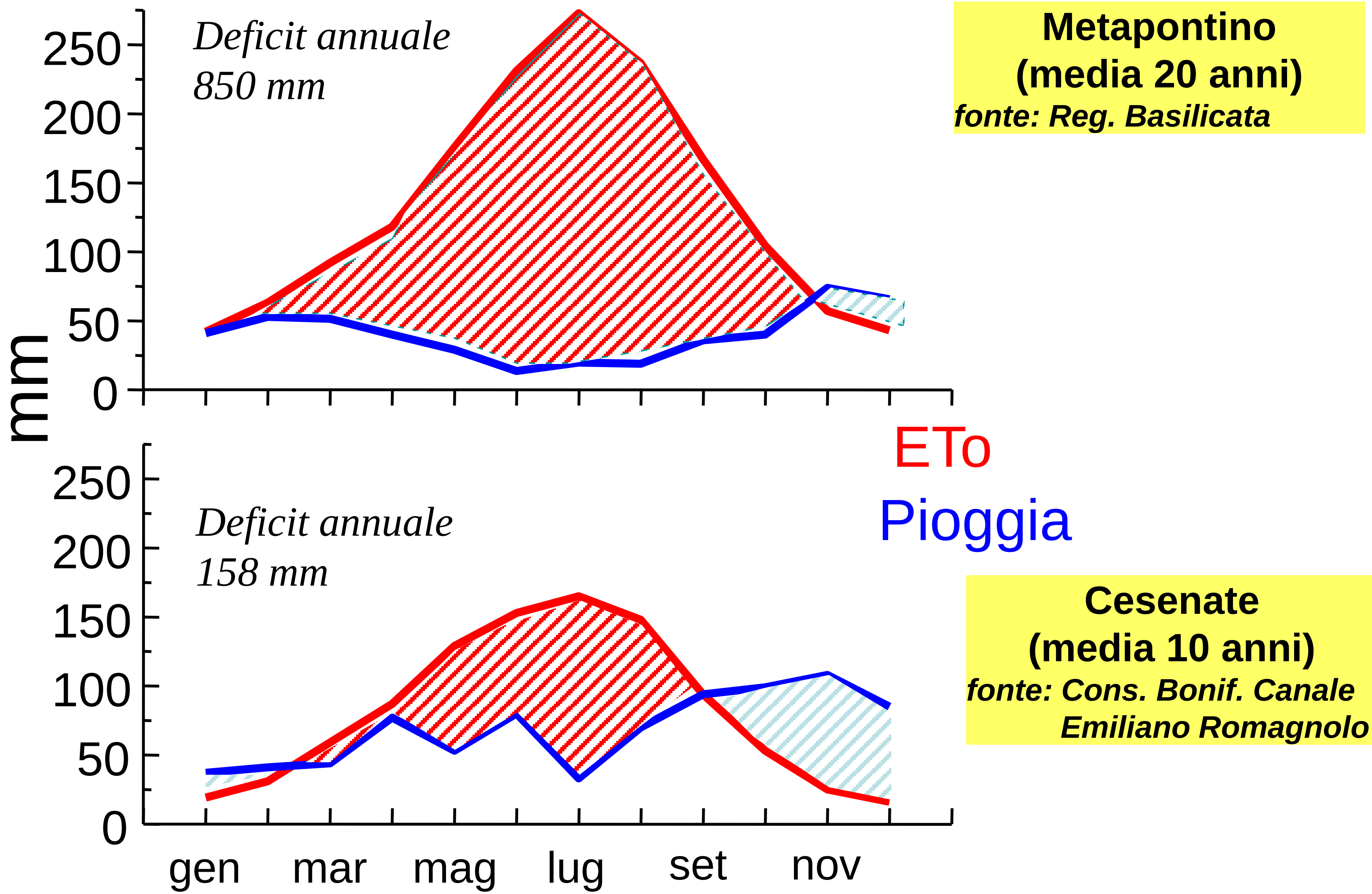
Sustainable

Conventional

…….as intestinal flora for humans……………..



roots with ifes and spores of glomus intraradices (10 X).



Metapontino
(media 20 anni)
fonte: Reg. Basilicata
Deficit annuale
850 mm
250
200
150
100
50
0
mm
ETo
Pioggia
Cesenate
(media 10 anni)
fonte: Cons. Bonif. Canale Emiliano Romagnolo
Deficit annuale
158 mm
gen
mar
mag
lug
set
nov

Optimizing irrigation in mature orchard:

DRIVING CRITERIA

IRRIGATION SHOULD BE SCHEDULED WHEN the water content in the first 50 cm of soil volume explored by root system APPROACH the Readily Available Water (RAW) threshold

HOW GROWER CAN BE ASSISTED IN?

Evaluation of soil water content through:

 # Use of soil humidity sensors

TDR-probe

Tensiometer

 # Daily computation of the soil-water balance

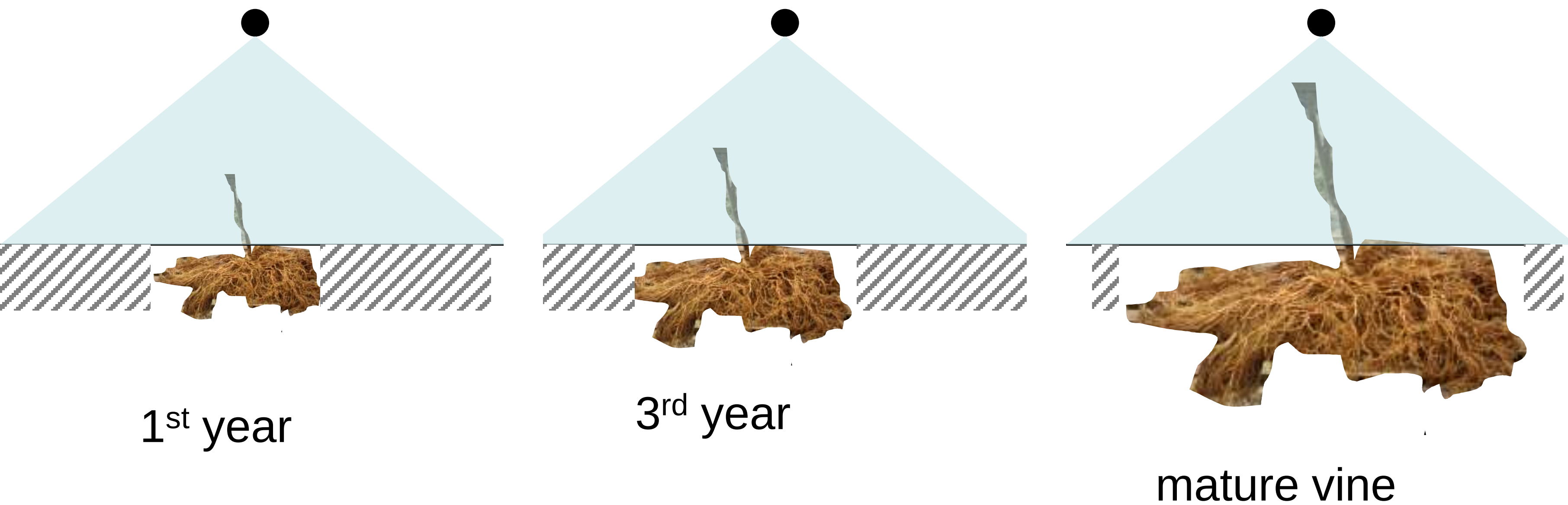
This requires:

access to daily ET0 and effective rainfall records

use of locally tested *K*c

knowledge of soil hydraulic properties and irrigated soil volume

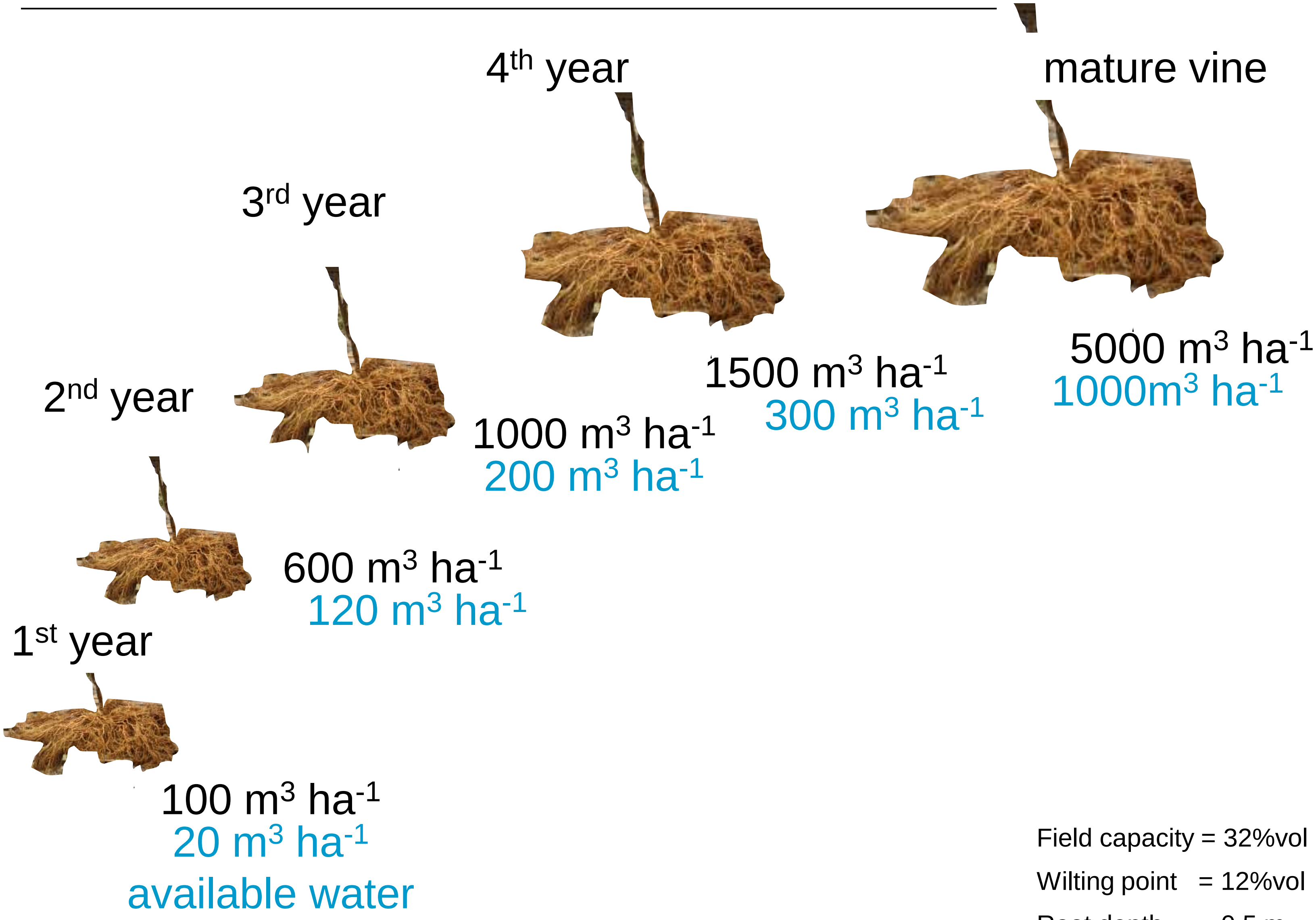
Irrigation system wetting the whole soil surface



 # Low irrigation method efficiency

(2-20% throughout 3 years after planting)

Soil volume explored by roots (Xiloyannis et al., 1993)

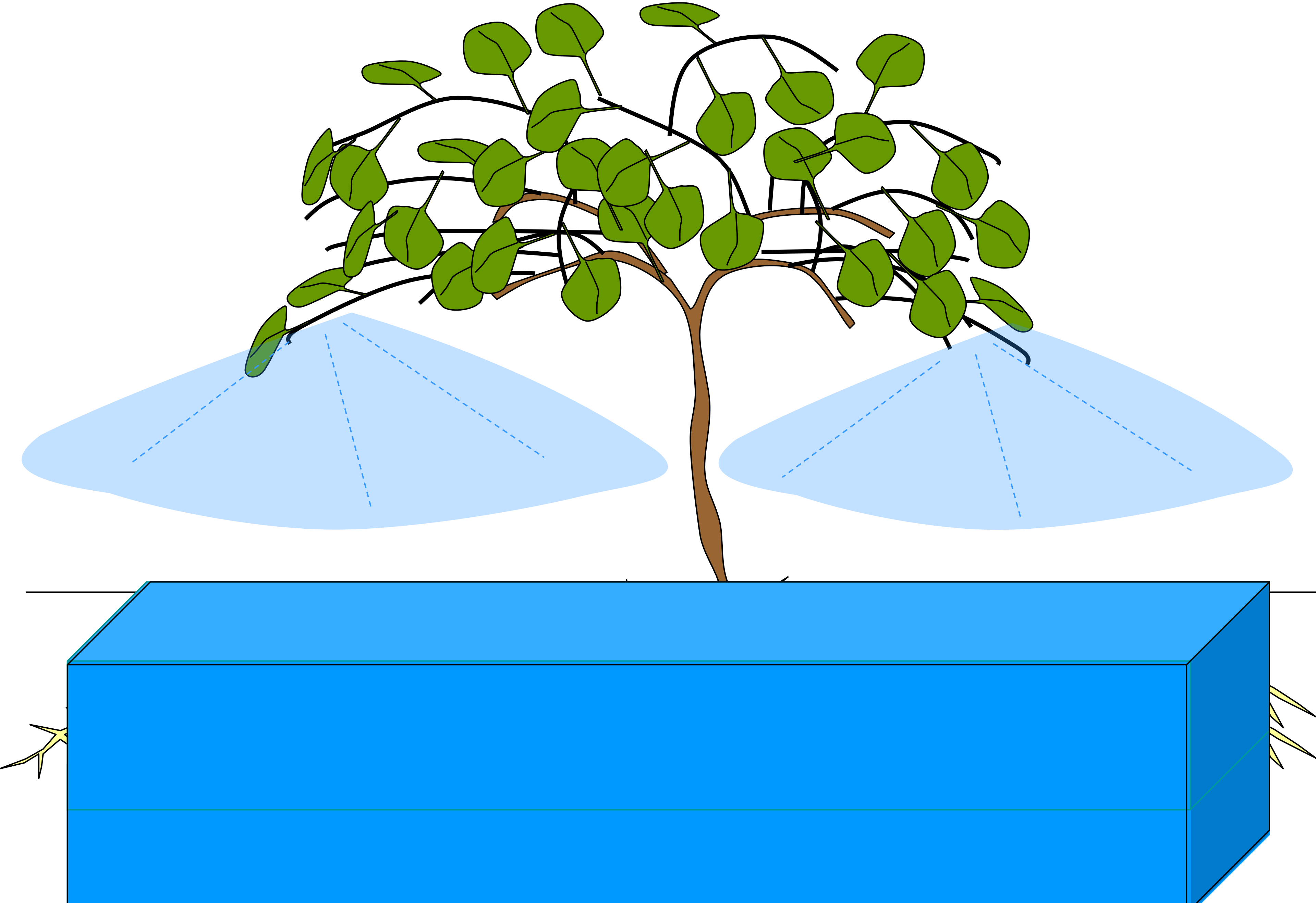


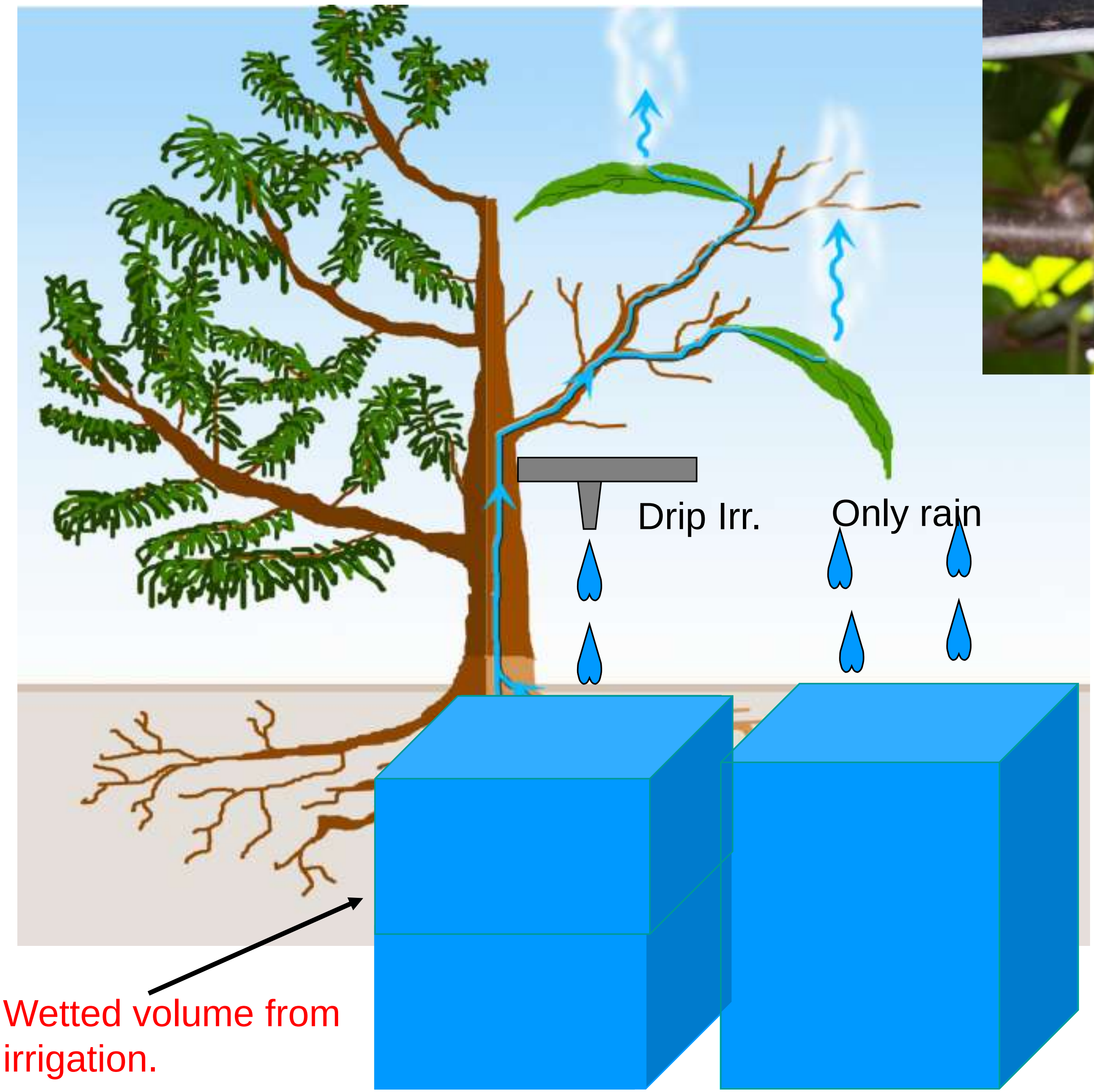
Amount of water that can be hold in the soil in a kiwifruit orchard irrigated by different irrigation systems (planting distances 5x4). Soil irrigated at field capacity to 0.5 m depth

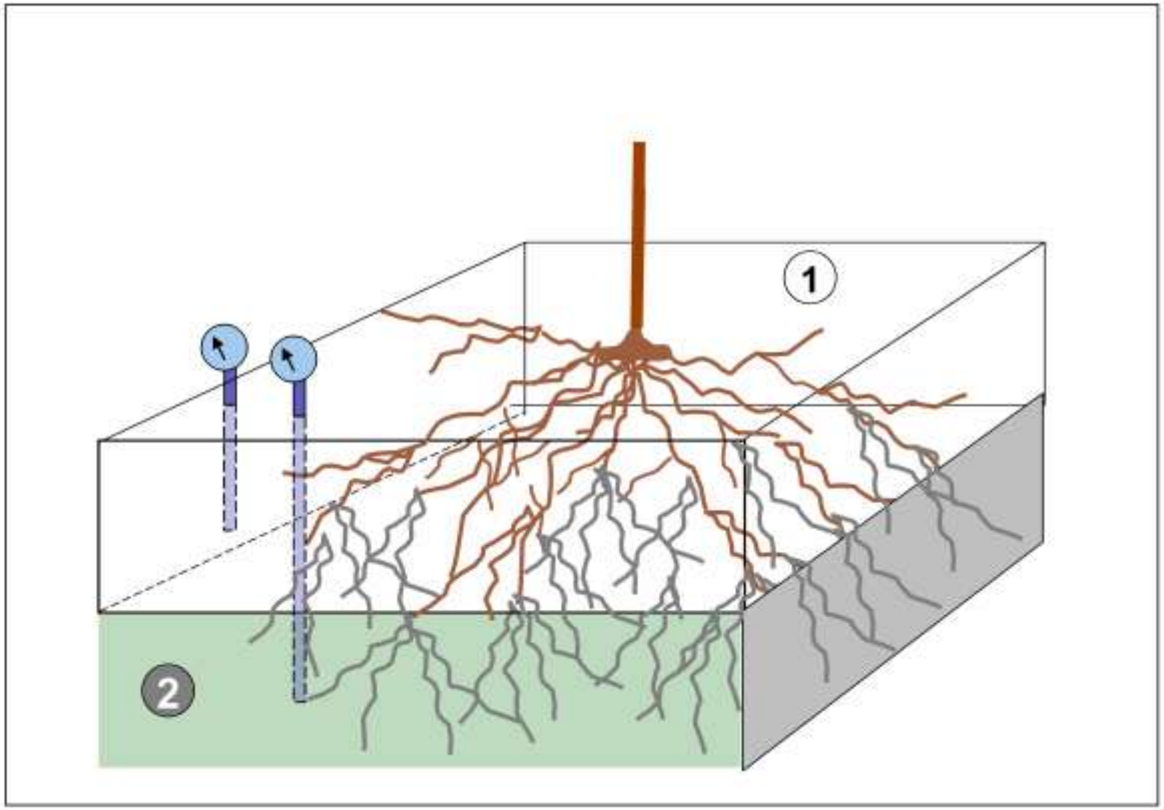
AW (Available Water) =20% vol (Field Capacity-Permanent Wilting Point)

Easy AW (amount of water that plants can absorb before stress)= 50% of A.W

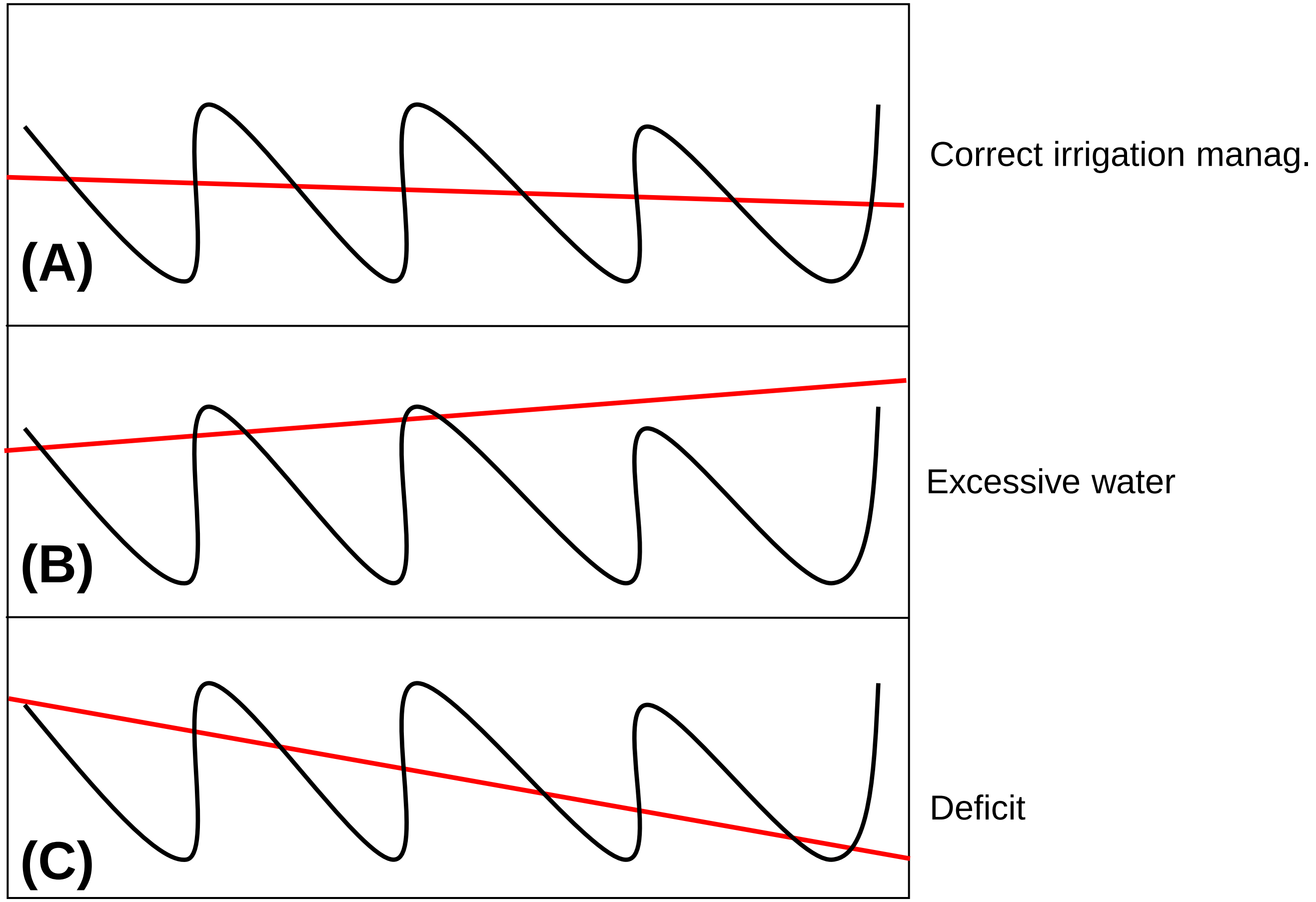
Irrigation system	Wetted surface m2	Depth (m)	Volume of irrigated soil (m3)	A.W m3	Easy W.A m3
Whole surface Efficiency 50%	10.000	0.5	5.000	500	**250**
Micro-Sprinklers Efficiency 70%	6000	0.5	3.000	420	**210**
Drip irrigation Efficiency 90%	2.000	0.5	1.000	162	**81**




Drip Irr.
Only rain
Wetted volume from irrigation.



1
2


(A)
(B)
(C)
Correct irrigation manag.
Excessive water
Deficit

summary

- **Fertigation should match vine nutrients demand to avoid environmental pollution and improve fruit quality**

- **Orchard tools are available to improve Ca absorption and accumulation in the fruits**

- **Use cover crops or minimum tillage to improve carbon footprint assessment, soil fertility and soil hydraulich characteristics**

- **More effort to improve the transfering of the knowledge to the growers**

K R G - University of Basilicata I T A L Y

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