SAFIR
Safe and High Quality Food Production using Low Quality Waters and Improved Irrigation Systems and Management

Combining methods for wastewater treatment and proper re-use by water saving irrigation

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The SAFIR project :

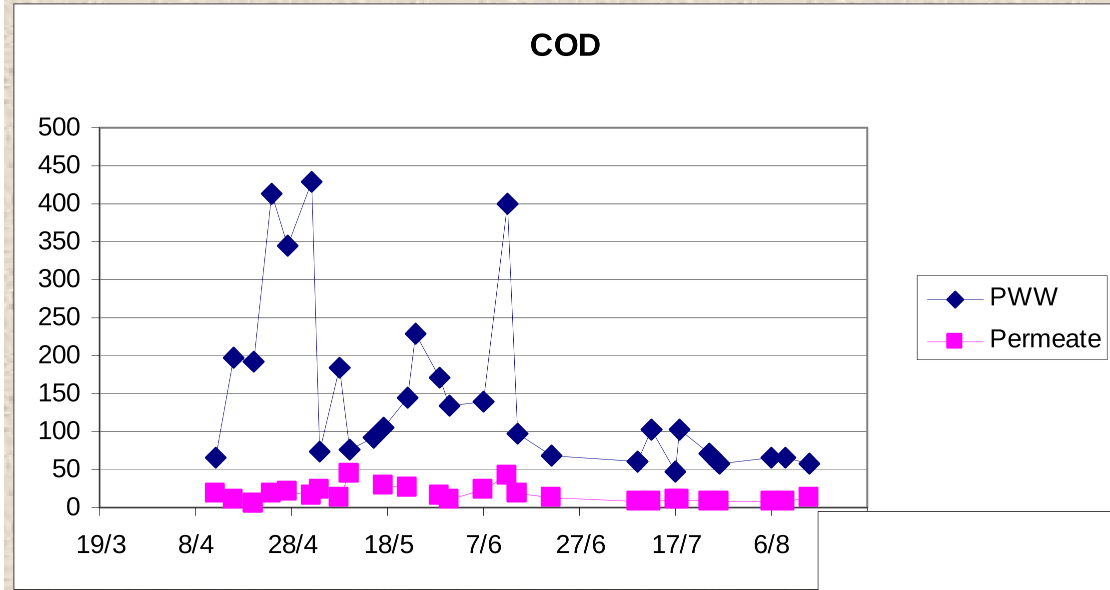
PNo.	Participant name	Participant short name
1	Danish Institute of Agricultural Sciences	DIAS
2	Consorzio di Bonifica di Secondo Grado per il Canale Emiliano Romagnolo	CER
3	Royal Veterinary and Agricultural University	KVL
4	Centre for Ecology & Hydrology	NERC, CEH
5	Bureau de Researches Geologique et Minieres	BRGM
6	London School of Hygiene & Tropical Medicine	LSHTM
7	Danish Research Institute of Food Economics	FOI
8	DHI Water and Environment	DHI
9	National Agricultural Research Foundation	NAGREF
10	Swiss Federal Institute of Food Economics	EAWAG
11	Institute of Plant Physiology, Polish Academy of Sciences	IPP-PAS
12	Faculty of Agriculture, University of Belgrade	UB
13	China Agricultural University	CAU
14	Chinese Academy of Agricultural Sciences	CAAS
15	Netafim, Drip Irrigation Technology	Netafim
16	Stazione Sperimentale per l'Industria delle Conserve Alimentari	SSICA
17	Grundfos Management A/S	Grundfos

Water treatment methods:

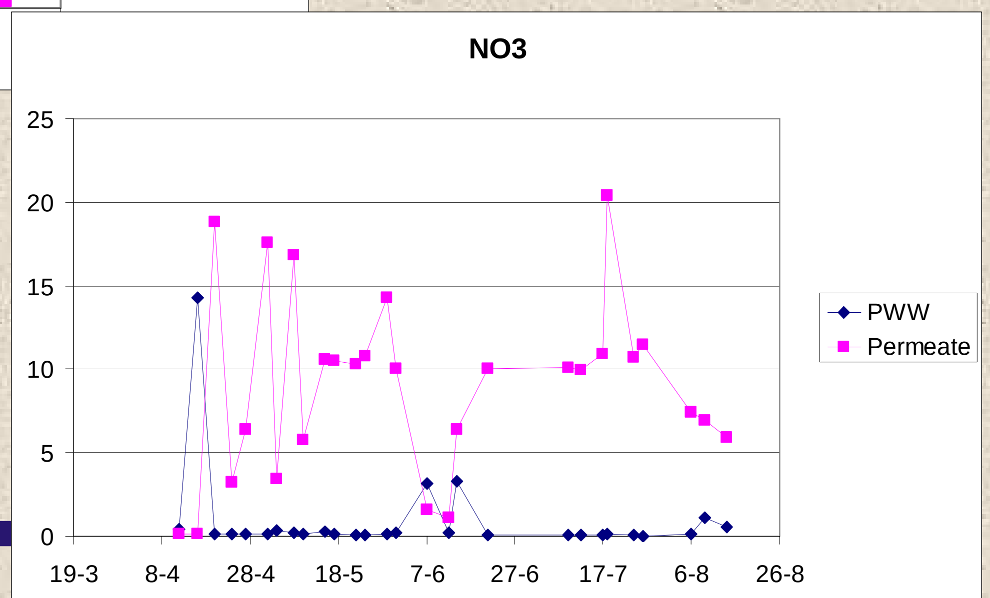
Membrane Bio-Reactor (MBR) treating primary treated wastewater near Bologna:

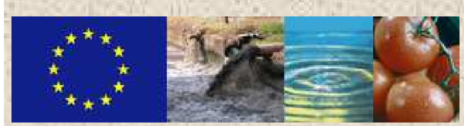
Water treatment methods:

Results of Membrane Bio-Reactor (MBR) treatment:



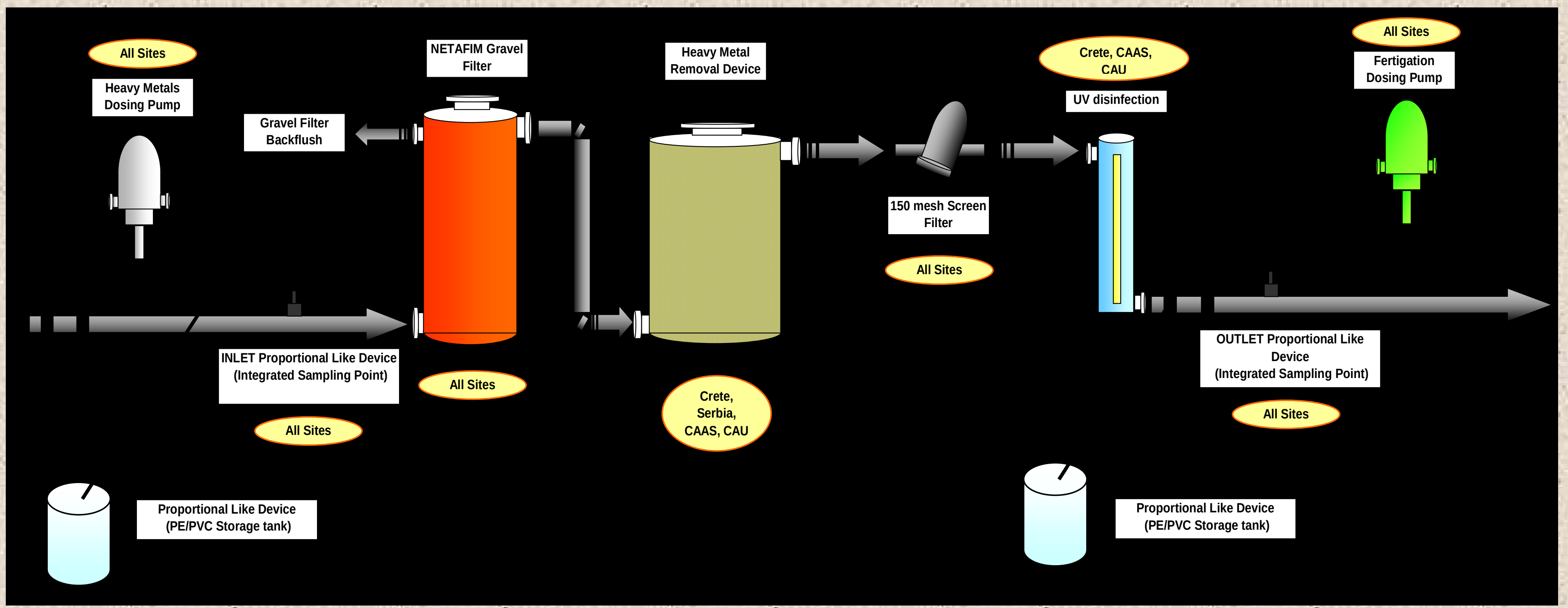
Average production: 8.4 m³/d



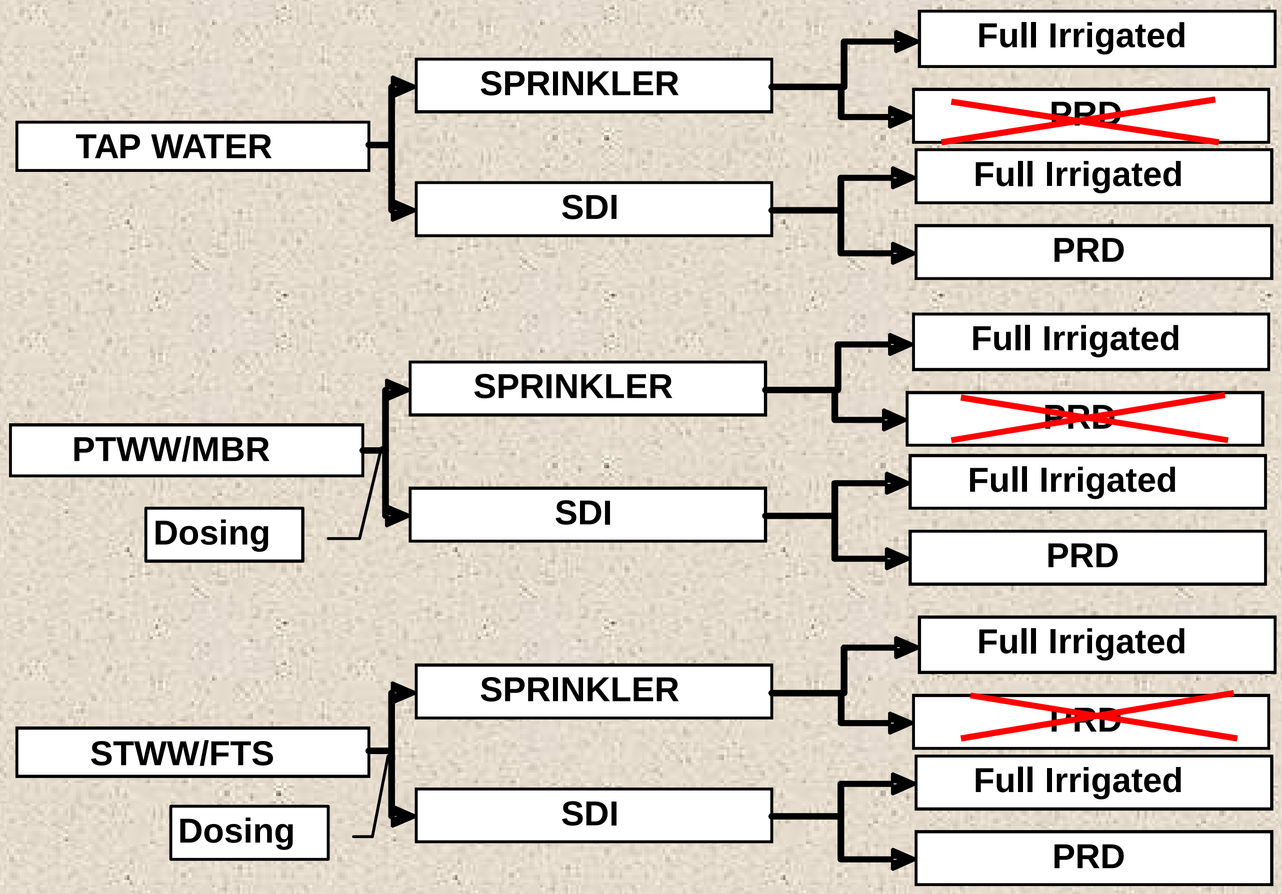


Water treatment methods:

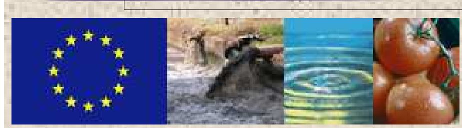
Field Treatment System (FTS) used at 5 field sites for less polluted water:



Irrigation methods:

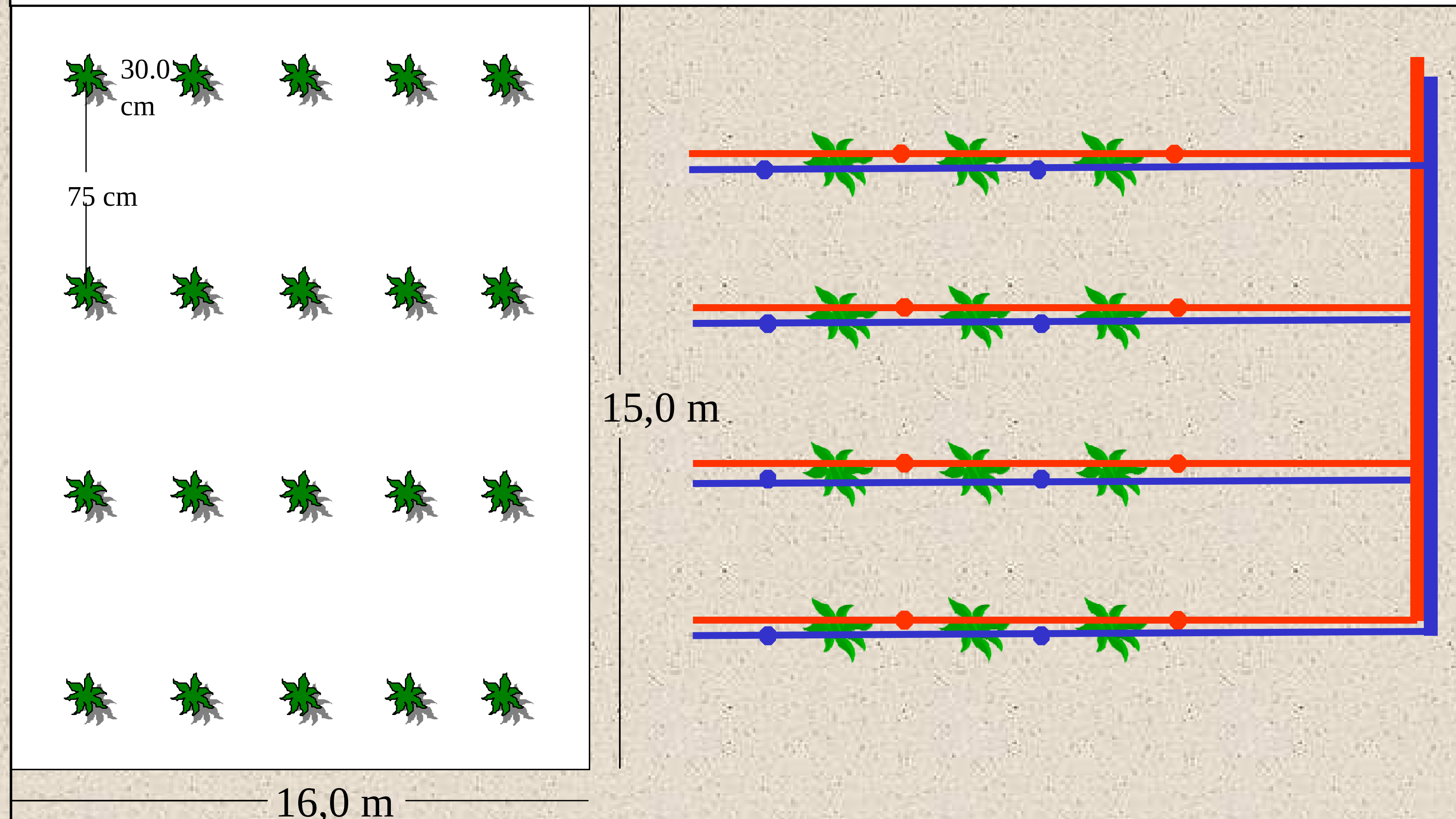


Partner 2 CER Italy
Potato + Processing Tomato
Tot 9 treatments - 27 plots per crop

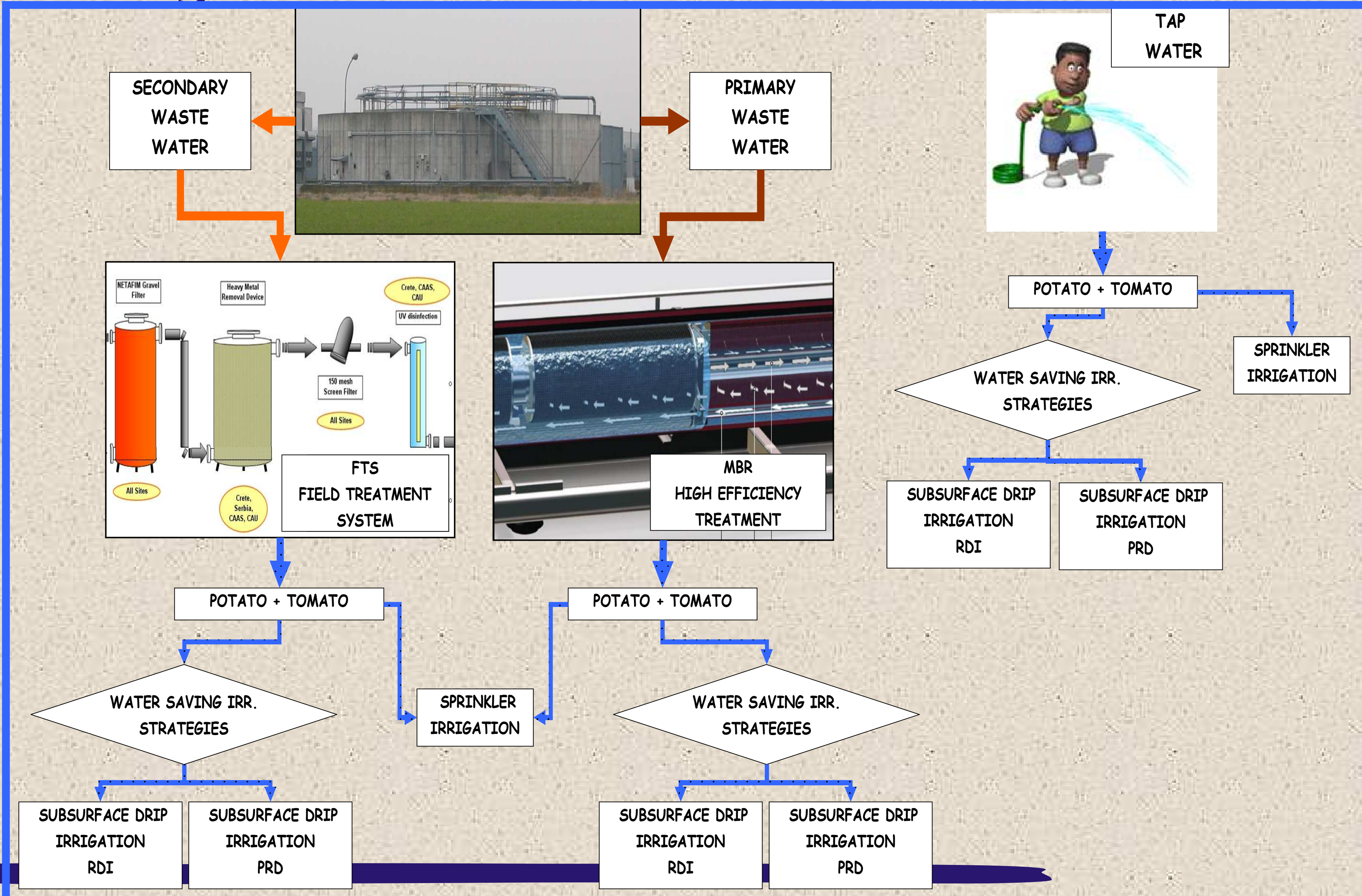


Irrigation methods

Experimental Partial Root-zone Drying (PRD) drip system and its placement with respect to potato plants



Irrigation methods:



Field scale models

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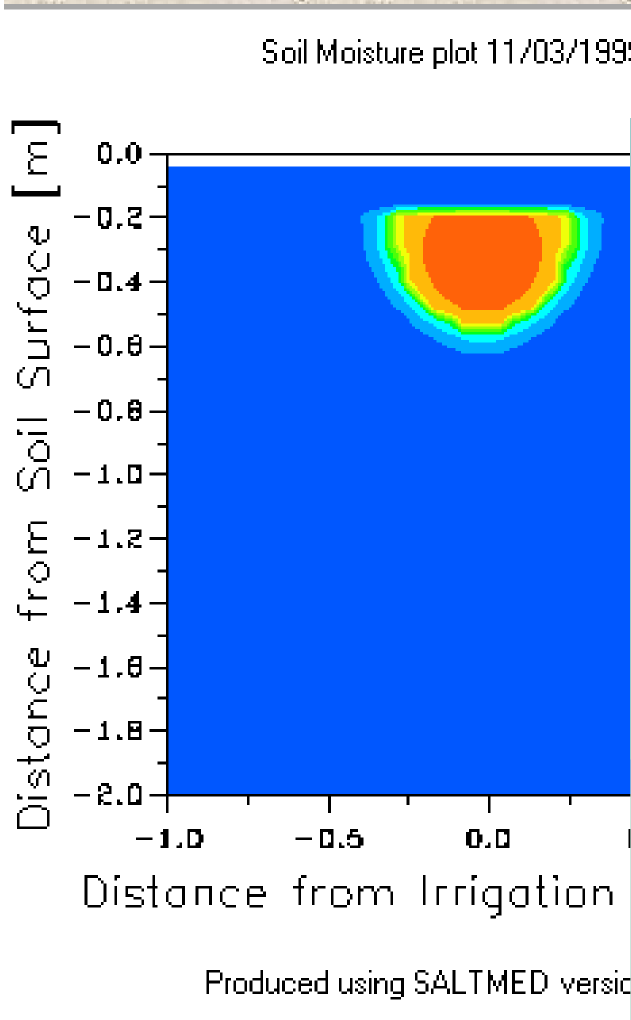
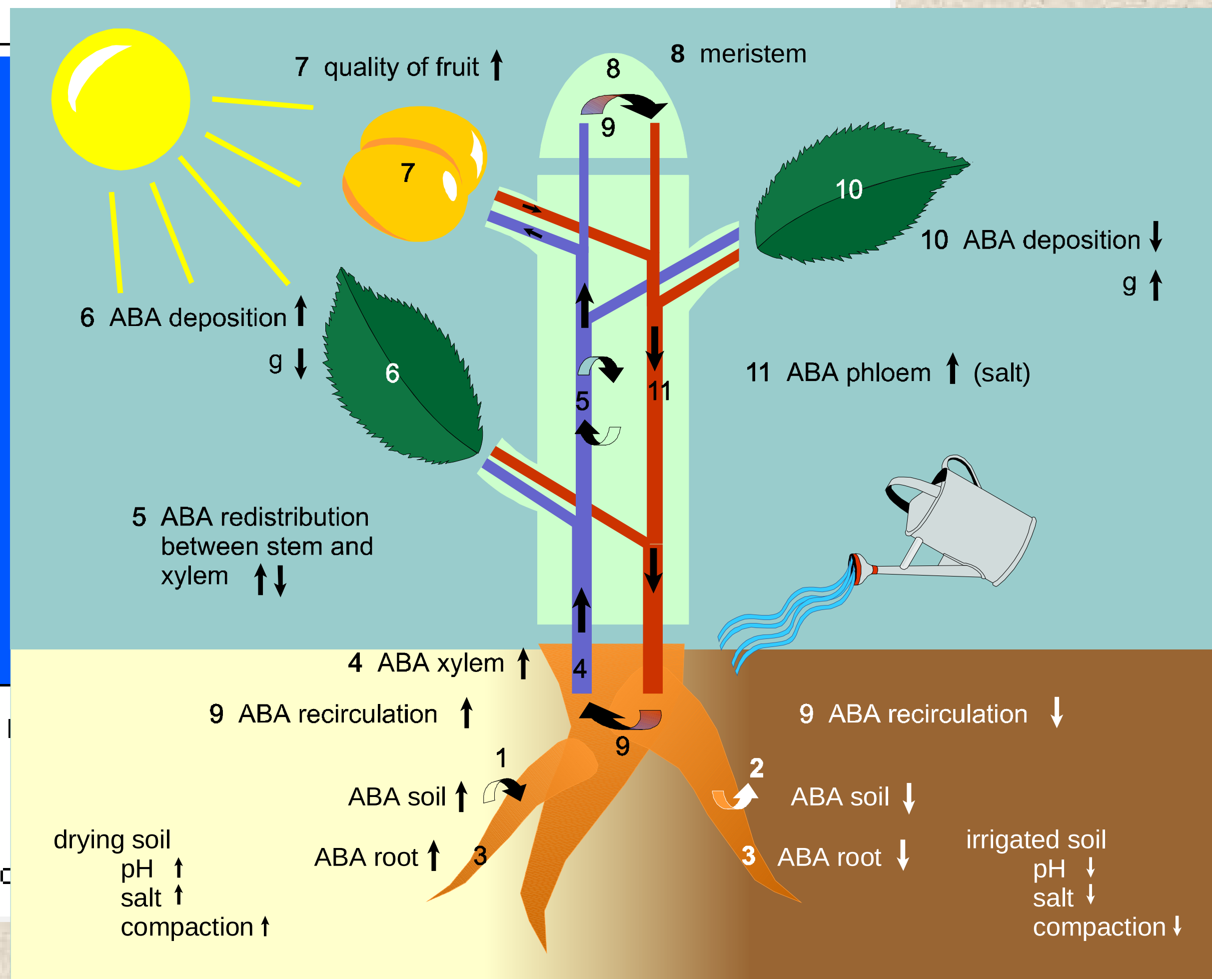
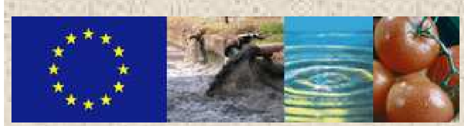




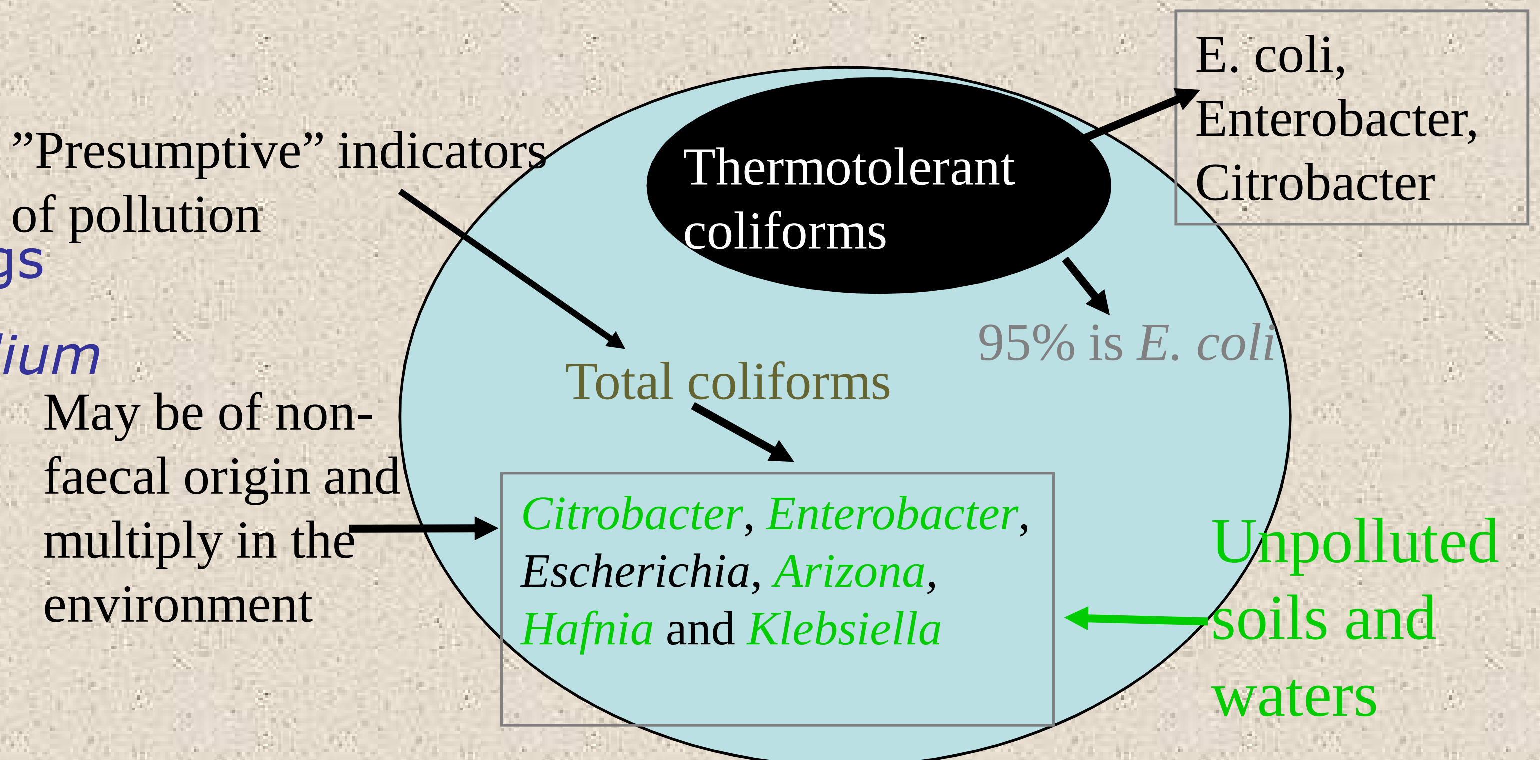


Impact studies and risk assessment

Safety of Food and Environment – Pathogens and Heavy Metals

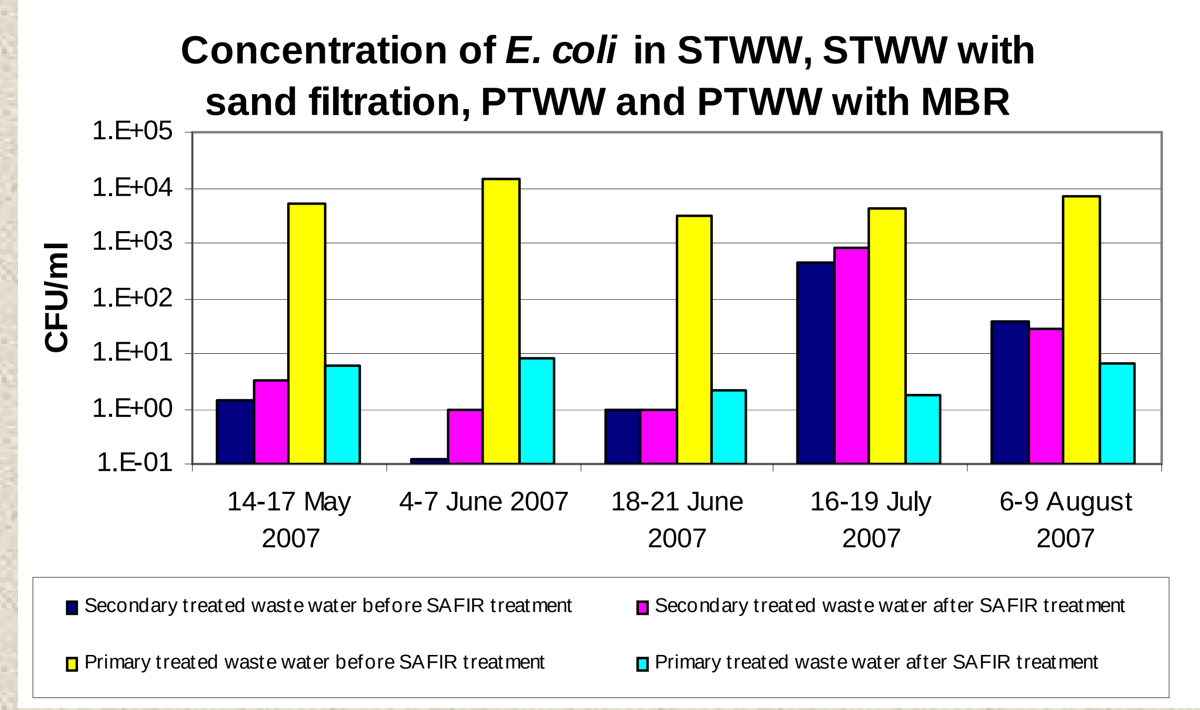
Helminth eggs

Cryptosporidium and *Giardia*

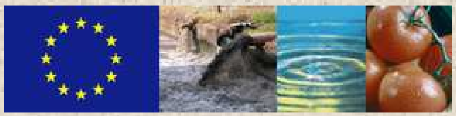


Impact studies and risk assessment

Safety of Food and Environment – Pathogens and Heavy Metals



Bologna, Italy: Sand filtration has no effect on *E. coli*. MBR reduces number of *E. coli* (-3-log). Soil from surface of potatoes all negative for *E. coli* whereas some soil samples (tomatoes) positive for *E. coli*. Potatoes and tomatoes all negative.



Impact studies and risk assessment

Quality of ±Processed Food

Evaluation of fresh matter food quality

Physical and chemical characteristics assessment

Industrial processing of the harvested vegetables into stabilizes commercial products (tomato puree and potato flakes)

Physical-Chemical analyses done in food samples:

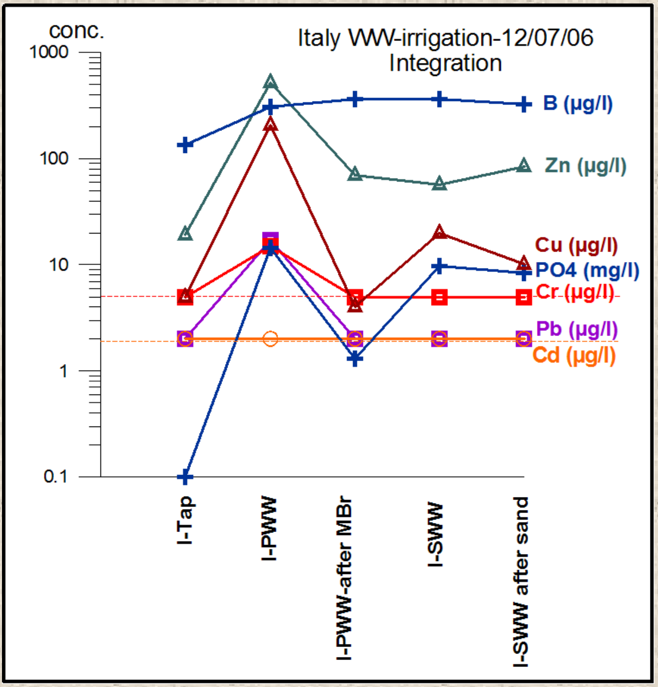
Analyses of Minerals
(Cd, Cr, Pb, Fe, Cu, As, Ni, Zn, Hg, Sn, P, Mg, K, Na, Na, K, P, B)

Analysis of microelements
(Se, Li, B)

Analysis of quality markers
(Total Solids, pH, Hunter Colour, Sugars, Tot.Acidity, Consistency, $NO3^{-}$ N tot)

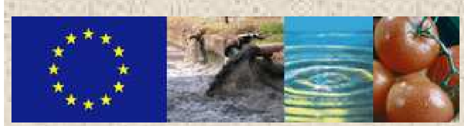
Impact studies and risk assessment

Pollution of the Environment
- Inorganic compounds



Italy 2006-season

	LOQ	I2-integ-TapWater 02/08/06	I2-integ-I°Before 02/08/06	I2-integ-I°After 02/08/06	I2-integ-II°Before 02/08/06	I2-integ-II°After 02/08/06	I2-WW-Tap 19/09/06	I2-WW-I°Before 19/09/06	I2-WW-II°Before 19/09/06	I2-WW-II°After 19/09/06	I2-integ-Tapwater 19/09/06	I2-integ-II°Before 19/09/06	I2-integ-II°After 19/09/06
No or uncertain effect													
COT	0,5	1,2	15,7	12,2	4,9	4,6	1,1	44,8	5,9	1,9	0,8	5,6	6,2
Ca	0,5	36,8	89,5	70,2	96,7	88,1	115,4	147,2	111,6	116,1	115,4	109,2	109,3
Mg	0,5	23,5	27,7	18,6	21,6	23,5	22,2	30,7	25	22,7	24,8	24,3	24,4
Na	0,5	29,1	138,3	72,5	109,2	118,8	31,8	281,8	38,6	31,8	30,8	133,1	115,7
K	0,5		14,1	7	16,5	17,7	2,7	15,9	7,8	2,9	2,8	15,4	13,7
HCO3	5						354	595	466	367			
Cl	0,5	19,4	203	95	132,2	136,3	28,4	491,7	25,7	25,6	25,6	154,1	134
SO4	0,5	78,5	93,3	50	89,4	93,7	98,8	111,6	54	93	134,2	120,1	168,7
PO4	0,1	< LQ	8,2	12	35,2	32,1	< LQ	9,8	12	0,8	< LQ	9,7	8,5
F	0,1						0,2	0,2	0,2	0,2			
As	1	< LQ	3,7	2,2	3,5	3,9	< LQ	< LQ	< LQ	< LQ	< LQ	3,2	3
B	10	134	338	189	393	422	131	240	139	127	145	518	492
Cu	1	< LQ	5	< LQ	12	8	12	4	< LQ	46	16	20	16
Li	1	15	21	13	16	16	16	21	15	15	17	19	20
Mn	5	< LQ	26	95	< LQ	< LQ	11	89	150	17	< LQ	18	16
SiO2	0,5	16,9	18,7	18,3	20,3	22,1	14,5	16,7	25,3	15,4	15,6	17,4	16,4
Sr	10	823	898	650	740	692	882	1157	1025	880	998	923	937
Zn	5	< LQ	11	< LQ	10	9	546	30	< LQ	690	58	377	269
RSEC	0,1												
COD	0,5						1,1	27,2	2,6	1,2			
Most values < LOQ													
NH4	0,1						< LQ	69,3	1,5	< LQ			
CO3	5						< LQ	< LQ	< LQ	< LQ			
NO3	0,5						15,2	< LQ	< LQ	12,3			
NO2	0,01						< LQ	0,17	< LQ	< LQ			
Al	10	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	17	< LQ	< LQ	15	49	19
Cd	0,5	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ
Co	1	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ
Cr	5	5,6	10,8	9,4	7,5	7,4	0,7	1,9	0,7	0,6	< LQ	< LQ	< LQ
Fe	0,02	< LQ	< LQ	< LQ	0,04	< LQ	< LQ	0,03	< LQ	< LQ	< LQ	0,07	0,05
Ni	1	< LQ	3,1	4,5	4	4,6	74,2	3,8	3,5	61,4	5,5	4,8	7,5
Pb	1	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ
Se	1	< LQ	< LQ	< LQ	< LQ	< LQ					< LQ	< LQ	< LQ



Impact studies and risk assessment

Risk assessment according to WHO, 2006

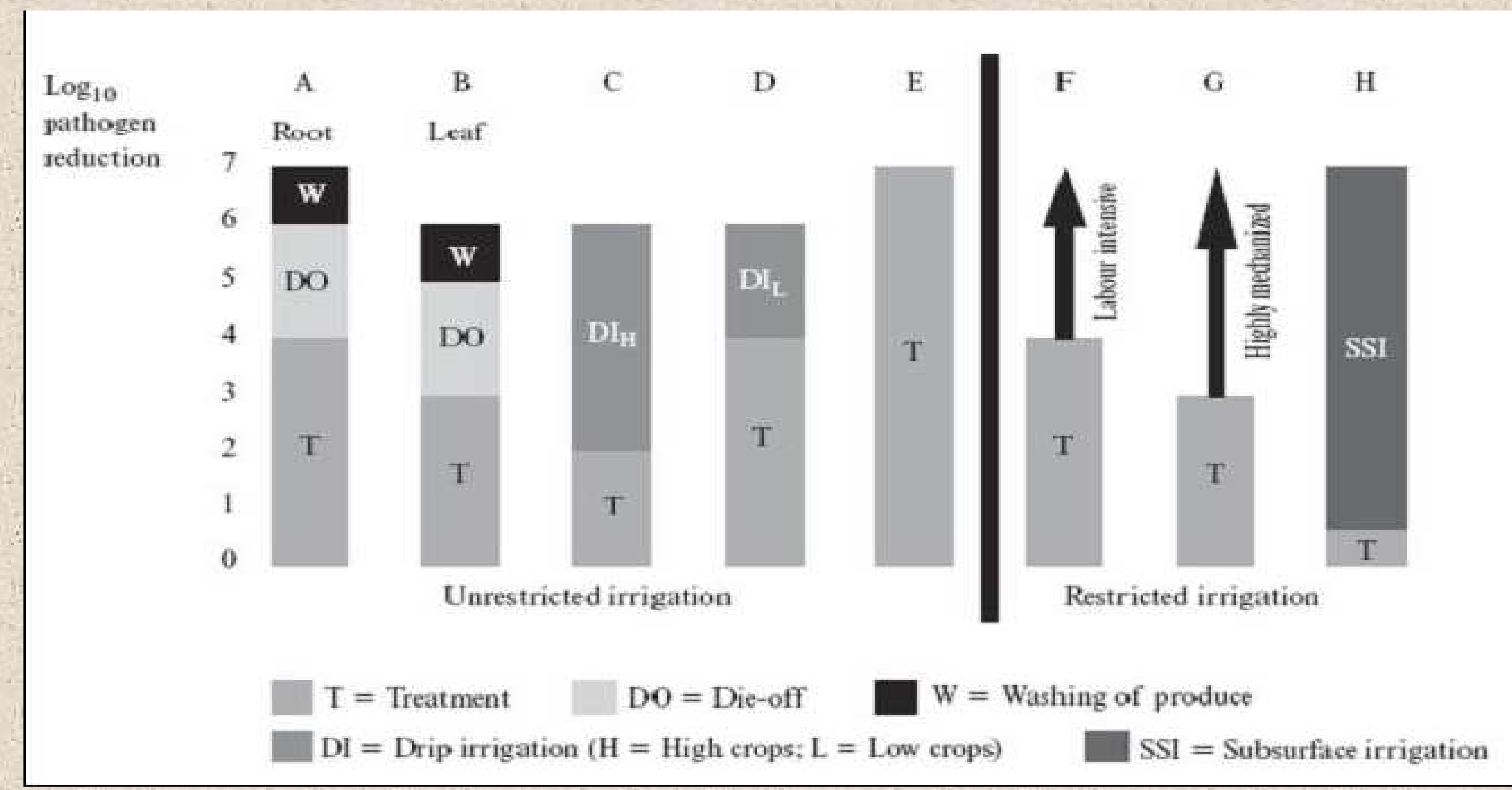
The revised guidelines do no longer only focus on wastewater treatment and crop restriction but offer a wider range of risk reduction measures such as localised (drip) irrigation techniques, food preparation measures like washing or peeling of produce and also takes natural die-off of pathogens on produce into consideration.

Table 1 Health based targets for wastewater use in agriculture (WHO, 2006)

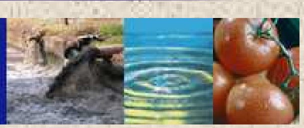
Exposure Scenario	Health based Target (DALY per person per year)	Log10 Pathogen reduction needed	Number of Helminth eggs per litre
Unrestricted Irrigation	$\leq 10^{-6}$		
Onion		6	≤ 1
Lettuce		7	≤ 1
Restricted Irrigation	$\leq 10^{-6}$		
Highly mechanized		3	≤ 1
Labour intensive		4	≤ 1
Localized (drip) irrigation	$\leq 10^{-6}$		
High growing crops		2	No recommendation
Low growing crops		4	≤ 1

Impact studies and risk assessment

Risk assessment according to WHO, 2006



The Disability Adjusted Life Years (DALY) indicator adds years of life expectancy lost due to premature death and duration of illness A widely used limit of tolerable risk, is 10^{-5} lifetime risk, or 1 excess case of cancer over a lifetime per 100,000 of the population ingesting water with a given chemical. In terms of DALYs rounded to a simple figure this disease burden is equivalent to 1 x 10^{-6} DALY per person per year (pppy) (WHO, 2003)



Impact studies and risk assessment

Risk assessment according to WHO, 2006

Involuntary ingestion of soil, subsurface irrigated by MBR treated primar

Soil qu
Mecha
Workin

SAFE

Risk (D
Rota Virus Mean 7.0 * 10^{-4}, SD 0.0006
Campylobacter Mean 3.0 * 10^{-5}, SD 0.00003
Cryptosporodium Mean 0.000, SD 0.00000

Impact studies and risk assessment

Risk assessment according to WHO, 2006

Consumption of tomatoes, surface irrigated by MBR treated primary wastewater

Produce

Consum

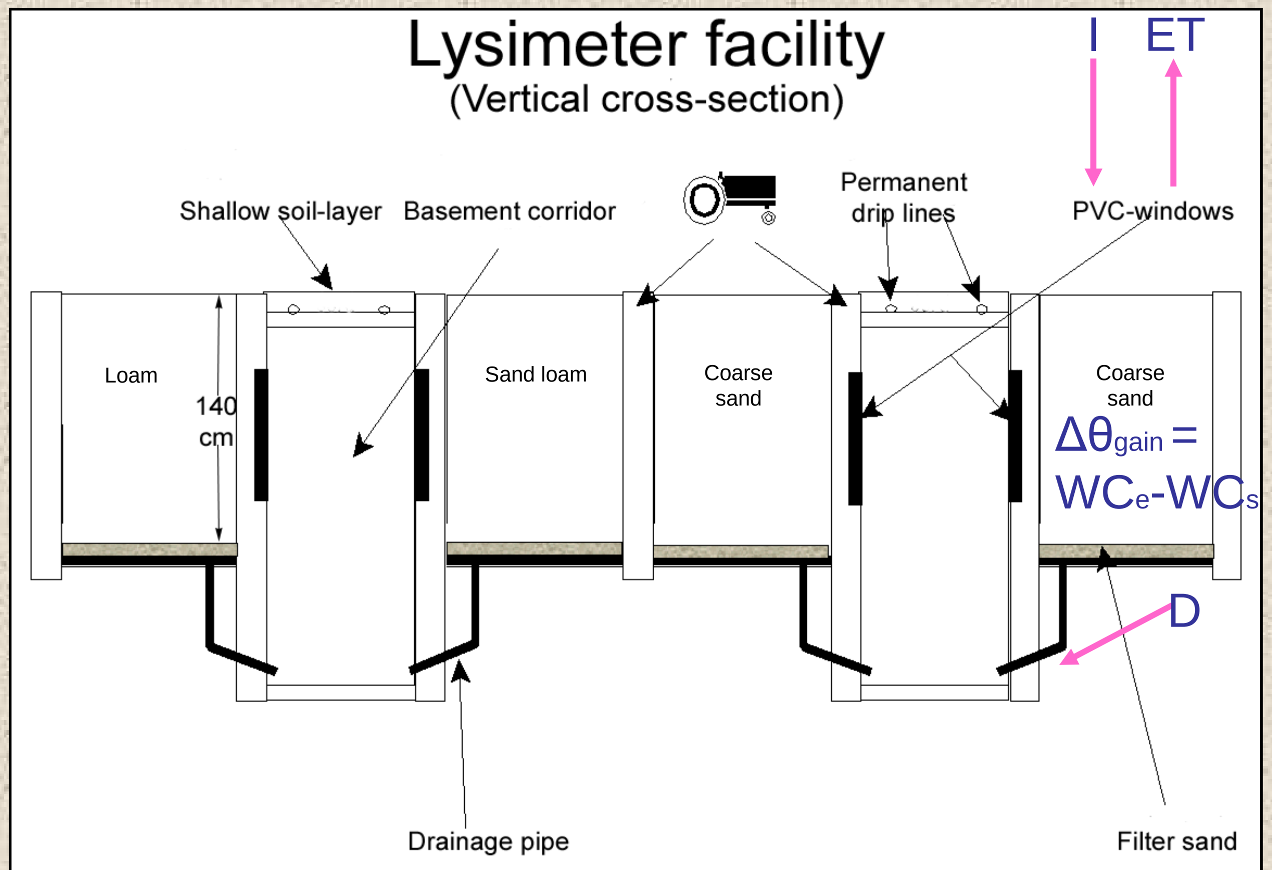
UNSAFE

Risk (DA

Rota Virus	Mean 2.0 * 10^{-2}, SD 0.03
Campylobacter	Mean 1.0 *10^{-3}, SD 0.001
Cryptosporodium	Mean 0.0001, SD 0.0002

Results on water saving irrigation

Semifield-facility, where all components in the water balance: irrigation/precipitation – drainage – soil water content – evapotranspiration, can be controlled or measured



$ET =$

$I - \Delta\theta gain - D$

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Results on water saving irrigation

Experimental Design:

3 soil types

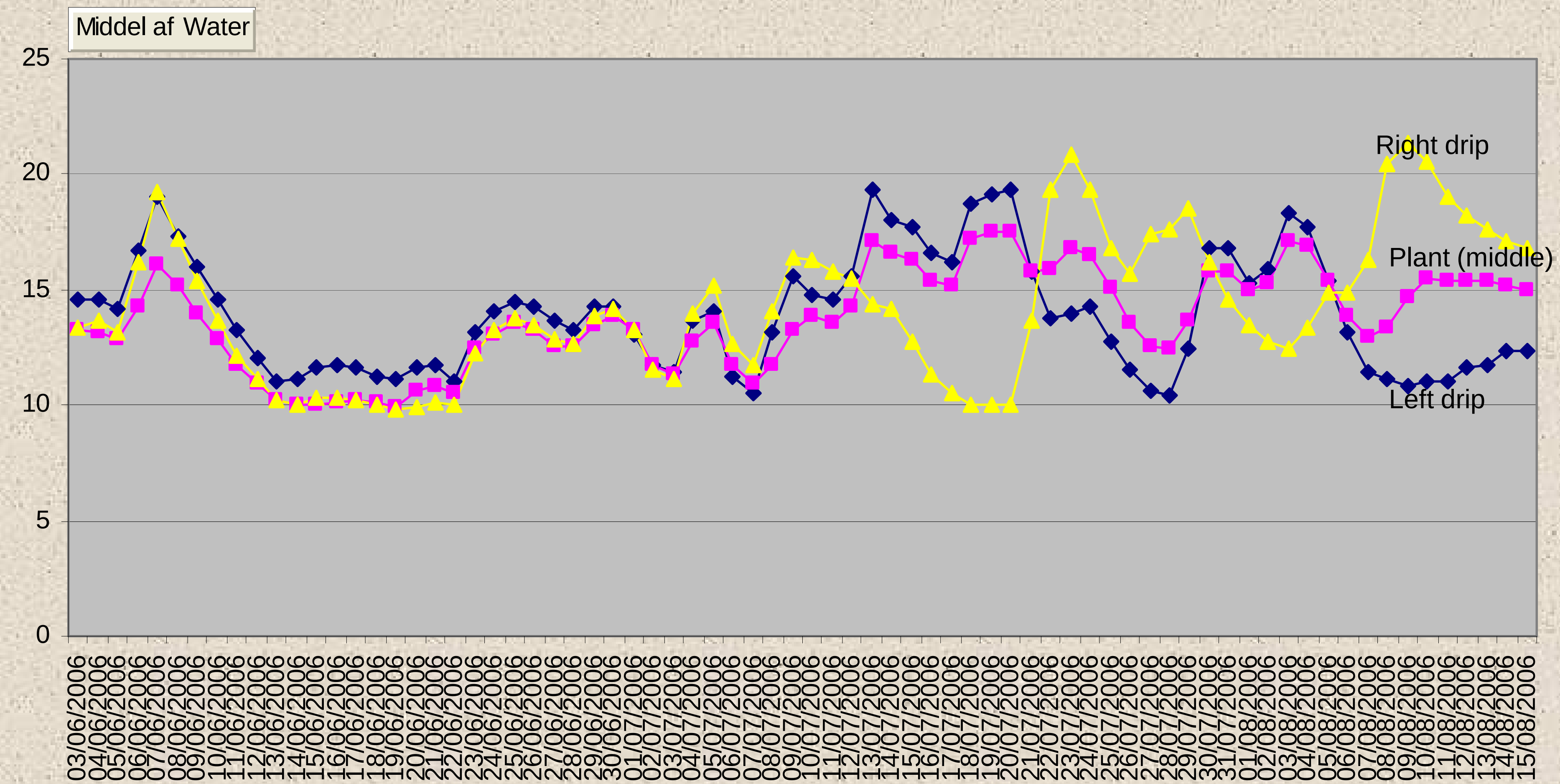
+

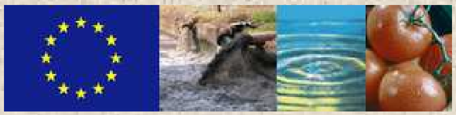
Irrigation treatments:

- FI: Drip irrigated daily to 25% deficit
- PRD1: PRD 70% in phase 1
- PRD2: PRD 70% in phase 2

Results on water saving irrigation

2006-season
Soil water content in PRD2:
Automatic horizontal TDR (sand loam in ridge z:0.08)





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Results on water saving irrigation

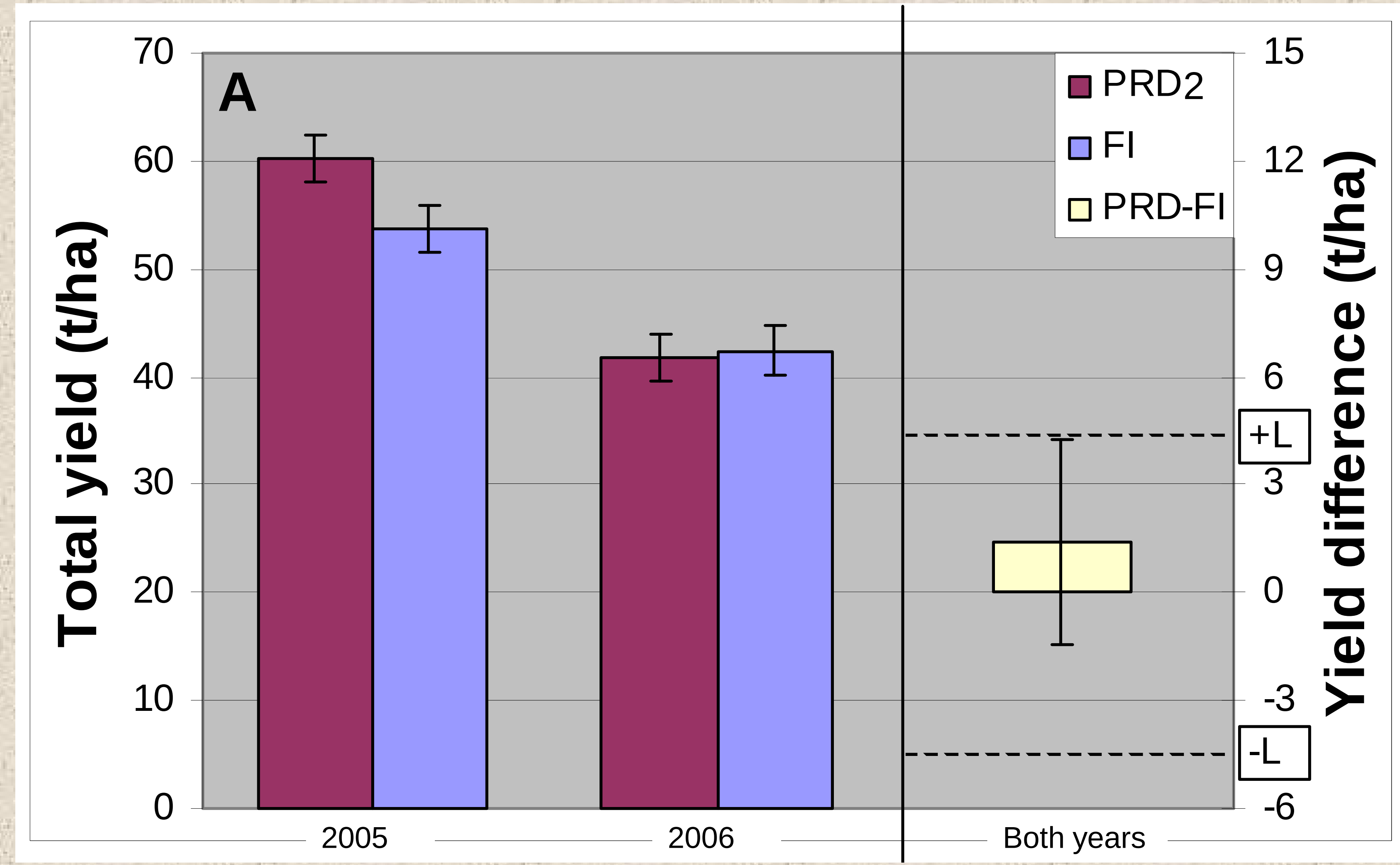
Water balance 2006:

Soil	Treatment	Irrigation (mm)	ΔSoil water (mm)	Drainage (mm)	Total evapotranspiration (mm)
Coarse sand	FI	285	13	36±8.0	262
	PRD1	245	0	40±5.6	205
	PRD2	243	24	37±6.5	230
Sand loam	FI	217	25	1±0.2	241
	PRD1	209	30	2±0.1	237
	PRD2	172	35	2±0.2	205
Loam	FI	253	25	26±0.3	252
	PRD1	213	35	4±1.3	244
	PRD2	208	40	3±1.0	245

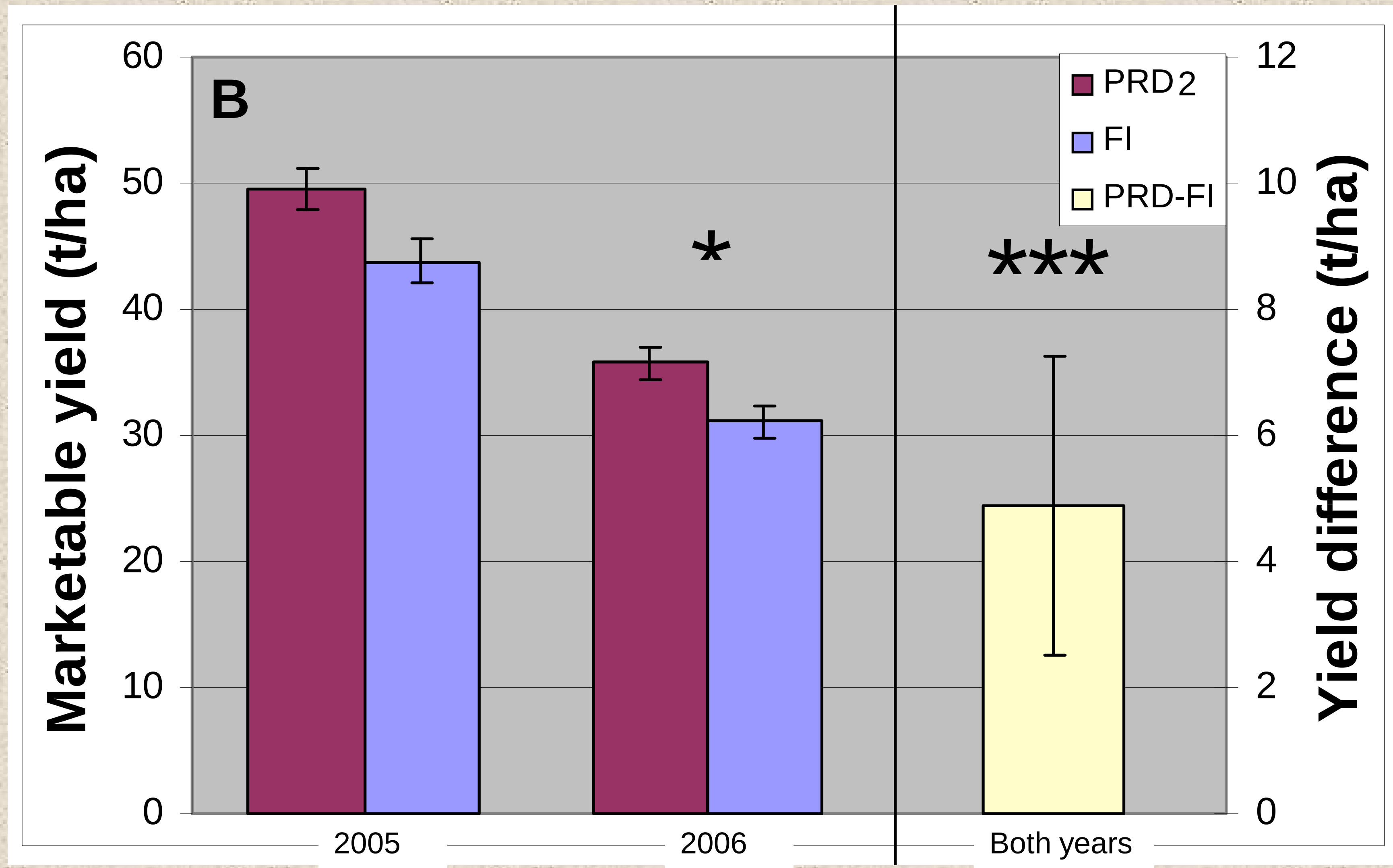
Results on water saving irrigation

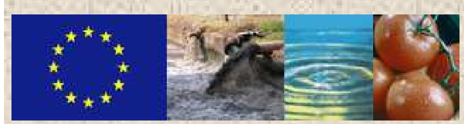
Size-grading of tubers:

Yield 2005-2006 sand: PRD2 v. FI

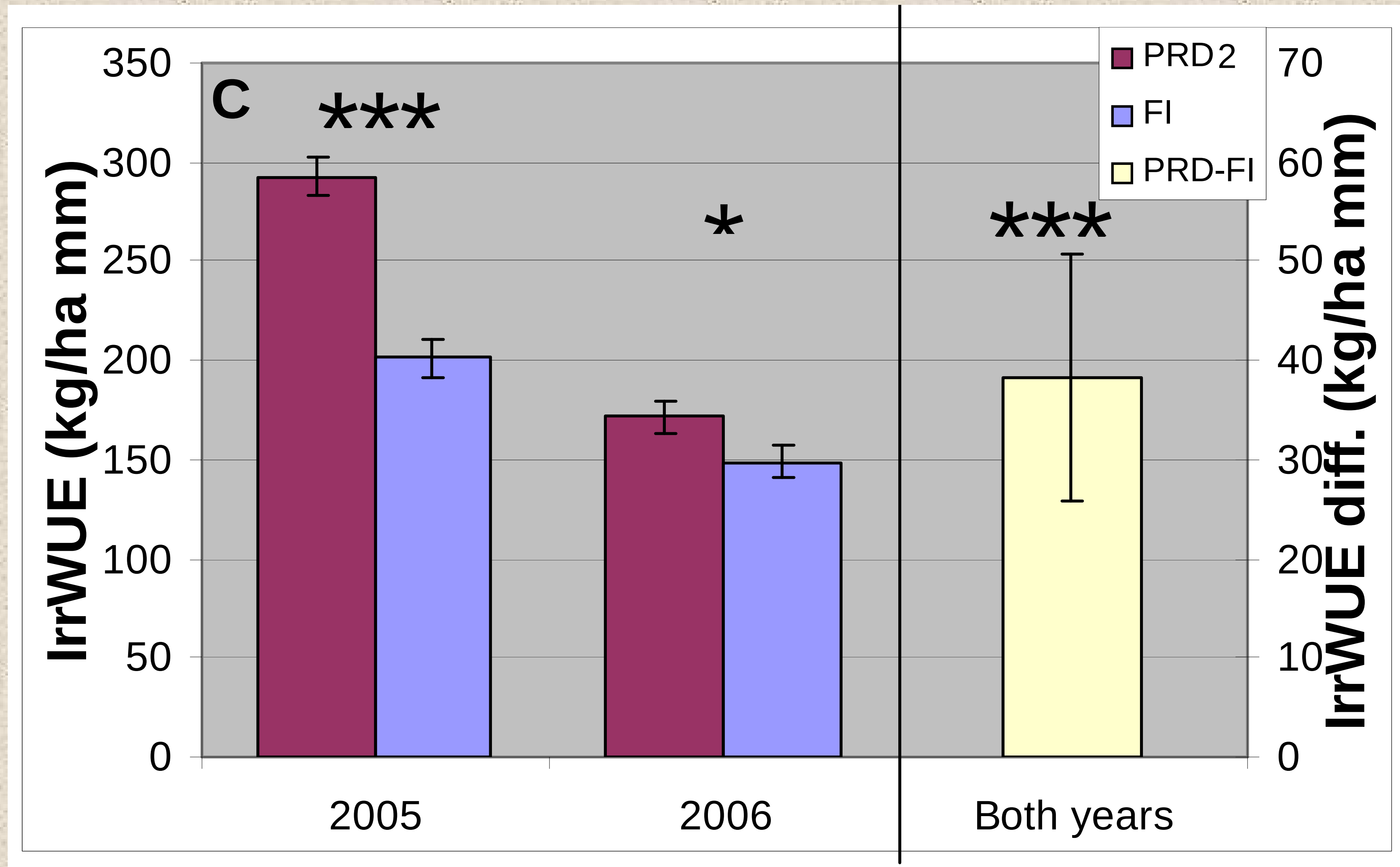


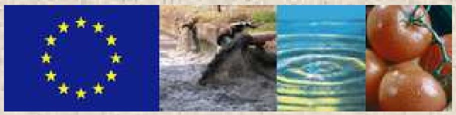
Marketable yield 2005-2006: PRD2 v. FI





Irr.WUE 2005-2006: PRD2 v. FI





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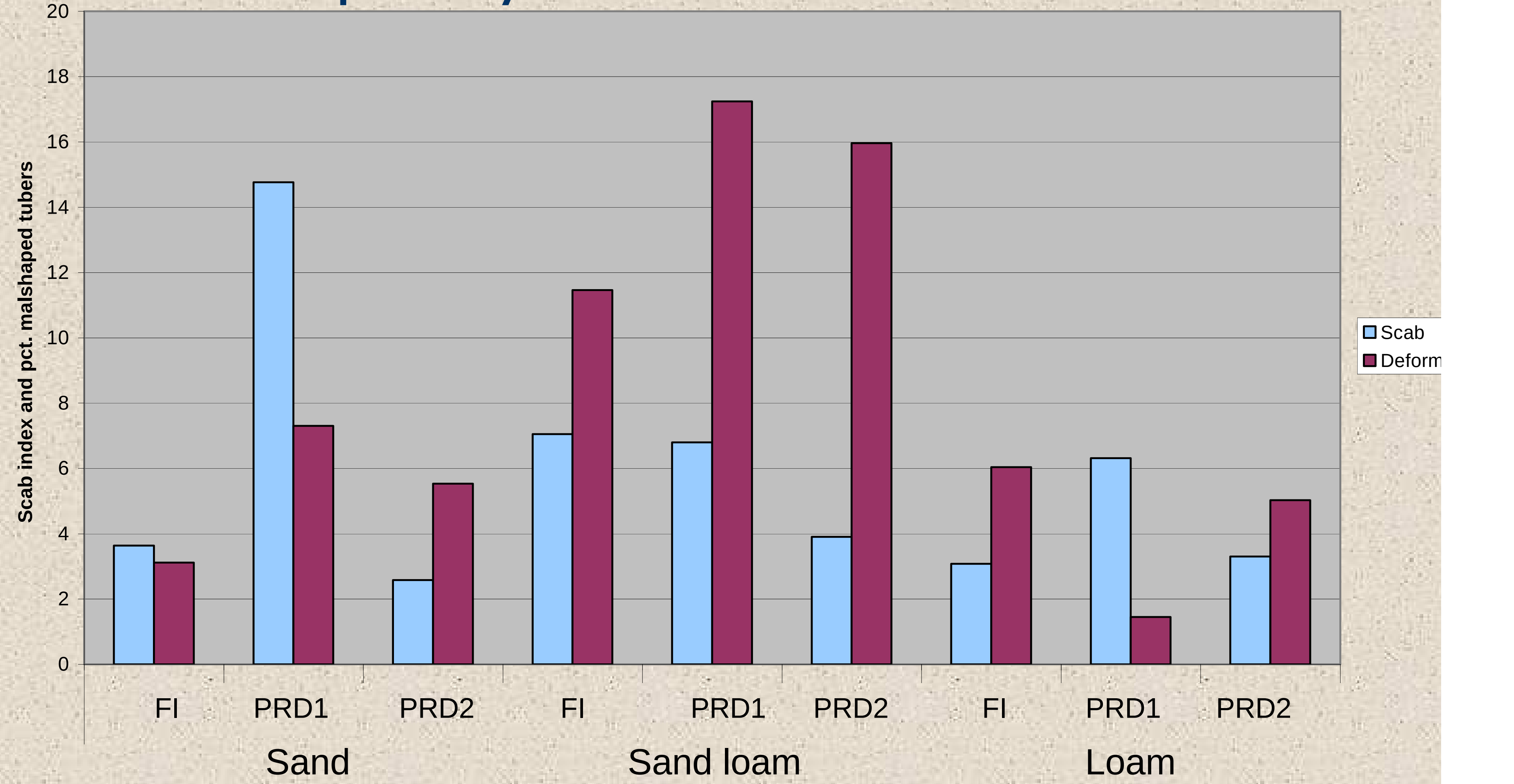
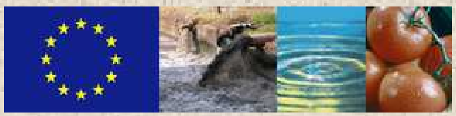
Results on water saving irrigation

Tuber quality 2006:





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Conclusions so far:

After 2 years of SAFIR experiments:

- The treatment systems combined with subsurface drip irrigation have worked well, i.e. the water quality produced is suitable for SDI.
- PRD 70% during the tuber filling stage produced yield and quality equivalent to a fully irrigated treatment and had 20% higher irrigation water use efficiency and a marketable yield that was 15% higher than FI. Management models for PRD irrigation will be developed for tomato and potato.
- The first lesson of SAFIR is that low quality water can be used. European and Chinese field experiments with potatoes and tomatoes grown on treated wastewater (vs. drinking water) indicate that contaminants and pathogens are very low in both the irrigation water delivered to the crops and the final product, and that food quality is good.

Conclusions so far:

- The SAFIR project will in addition provide data for risk assessment in general of various irrigation practices. This will help in setting standards and be used in defining good agricultural practice for re-use of water when developing product certification schemes.

Acknowledgement

Sven-Erik Jacobsen[2], Seyed Hamid Ahmadi[1], Finn Plauborg[1], Fulai Liu[2], Adriano Battilani[3], Martin Andersen[4], Michele Steiner[5], Georgios Psarras[6], Radmila Stikic[7], Guitong Li[8], Xuebin Qi[9], Anita Forslund[2], Wolfram Klopmann[10], Luca Sandei[11], Jeroen Ensink[12]

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