Biological control agents: solutions and constraints for sustainable crop production in a changing world.

S. Declerck

Microbiome-based Foods for Health and Sustainability
Brussels 23 February 2016

The challenges we face

Feeding a growing population

By 2050...

World population will grow to 9.2 billion = **growth > 25%**

Urbanization = **70%**

Food production must increase **by more than 60%** ...

and be sustainable

Climate change

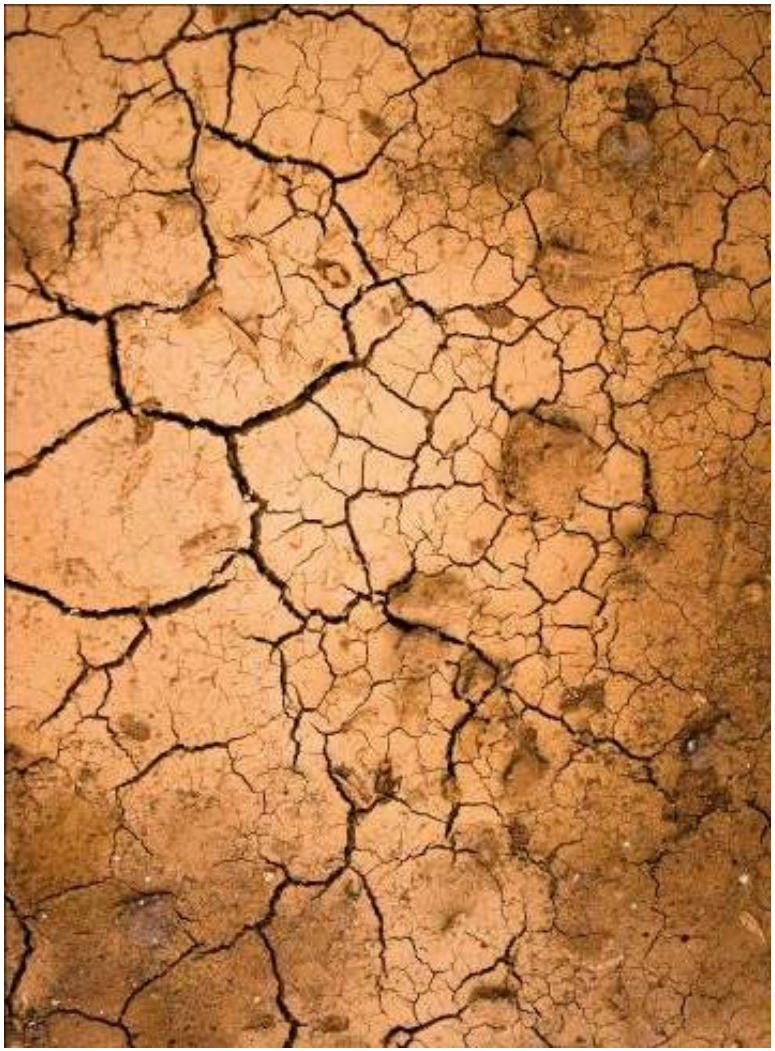
Temperatures rise up to 2.5 °C

New pests and diseases

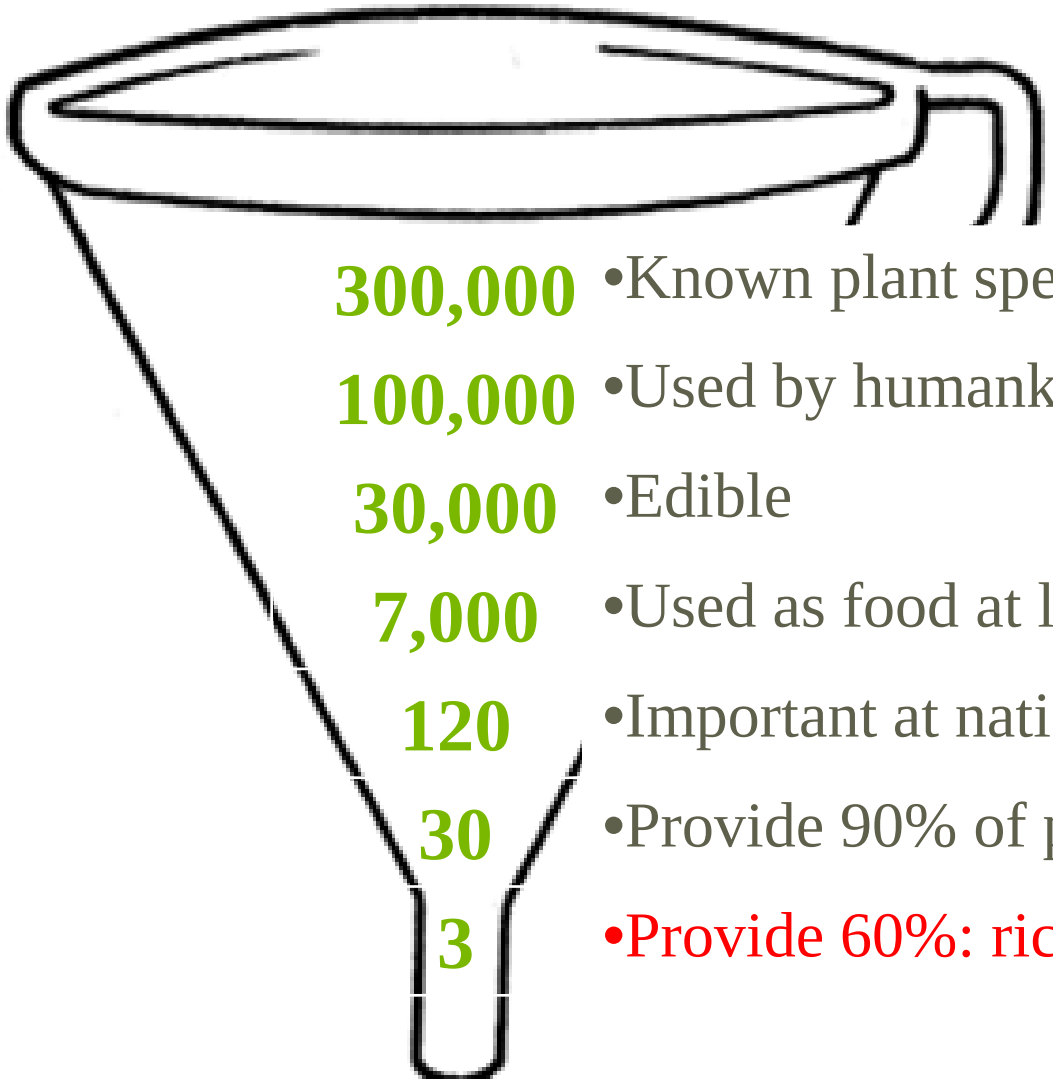
Water scarcity & desertification

Salinization

Increase in fertilizers and pesticides, irrigation economically impractical and at risk for environment



Increasing reliance on few plants



300,000 •Known plant species

100,000 •Used by humankind

30,000 •Edible

7,000 •Used as food at local level

120 •Important at national scale

30 •Provide 90% of plant calories

3 •Provide 60%: rice, wheat, maize

(Frison, personal communication)

Globalisation and increasing impacts of climate change

Plant health: global importance

Loss estimates: 30–40% in DC from ‘field-to-fork’

Threats have increased because of

- Globalisation
- Climate change
- Change in land use

How can agriculture meet these challenges?

We need to adapt...

Agricultural systems that produce **more** and **better** food under **harsher conditions** while **protecting the environment**

→ we need **a novel paradigm**

We have trillions of potential partners:

The microbes

Microbes & plants are intimate partners

Globally, soil contains 4–5 10^{30} microbial cells

TAXON	DIVERSITY	ABUNDANCE
Prokaryotes	100–9,000 cm^{-3}	4–20 × 10^{9} cm^{-3}
Fungi	200–235 g^{-1}	100 m g^{-1}
AMF	10–20 m^{-2}	81–111 m cm^{-3}
Protists	150–1,200 $(0.25\ g)^{-1}$	10^{4}–10^{7} m^{-2}
Nematodes (genera)	10–100 m^{-2}	2–90 × 10^{5} m^{-2}
Enchytraeids	1–15 ha^{-1}	12,000–311,000 m^{-2}
Tardigrades	?	?
Collembola	20 m^{-2}	1–5 × 10^{4} m^{-2}
Mites (Oribatida)	100–150 m^{-2}	1–10 × 10^{4} m^{-2}
Isopoda	10–100 m^{-2}	10 m^{-2}
Diplopoda	10–2,500 m^{-2}	110 m^{-2}
Earthworms (Oligochaeta)	10–15 ha^{-1}	300 m^{-2}

(Bardgett and van der Putten, Nature, 2014)

BCA’s in the market

Biopesticide industry = 2.1 billions/year (2011) = 5 % of chemical pesticides industry

Commercial bacterial biocontrol agents in EU

Product	Microorganism	Target Crop/ Pathogen	Company
Serenade	*B. subtilis* QST 713	Orchards, Apple, Pear/ *Venturia inaequalis* Orchards, stone fruits/*Monilia* Grapevines/ *Uncinula necator*, *Botrytis cinerea* Lettuce/*Bremia lactucae*	AgraQuest
Bacillus firmus I-1582 WP5	*Bacillus firmus* I-1582	Cucumber, Carrot/Nematode	Bayer CropScience AG
Cedomon	*Pseudomonas Chlororaphis* MA342	Barley/*Drechslera graminea*, *D. teres* Oat/ *D. avenae, Ustilago avenae* Wheat/*Tilletia caries*, *Stagonospora nodorum* Cereals/ *Microdochium nivale*	Bio Agri AB
Mycostop	*Streptomyces* K61	Ornamentals, Vegetables, Herbs/ *Fusarium, Pythium &Phytophthora*	Verdera Oy
Agree 50	*B.thuringiensis ssp. aizawai*, strain GC-91	Grapevine/ *Lobesia botrana*, *Eupoecilia ambiguella*	Mitsui AgriScience
Xen Tari	*B.thuringiensis ssp. aizawai*, strain ABTS-1857	Pepper/caterpillars	Valent BioSciences
Gnatrol	*B.thuringiensis ssp. israelensis*, strain AM65-52	Ornamental/ Sciarid flies	Valent BioSciences
Delfin	*B.thuringiensis ssp. kurstaki*, strains SA-11,12 & EG2348	Grapes/ *L.botrana*, *E.ambiguella*	Mitsui Agriscience
Belthirul	*B.thuringiensis ssp. kurstaki*, strain PB-54	Tomato/ *Helicoverpa armigera*	Probelte S.A
DiPel	*B.thuringiensis ssp. kurstaki*, strain ABTS-351	Cabbage/*Mamestra brassicae*	Valent BioSciences
Novodor	*B.thuringiensis ssp. tenebrionis*, strain NB 176	Potato/ *Leptinotarsa decemlineata*	Valent BioSciences

(Velivelli et al. TibTech, 2014)

BCAs constraints and risks

- Treatments that work in the simplified conditions of the laboratory frequently fail !

  - competition with established microbial communities,
  - inadequate environmental conditions or timing.
  - Inadequate agricultural practices

Understanding resilience of microbial communitie: a necessity

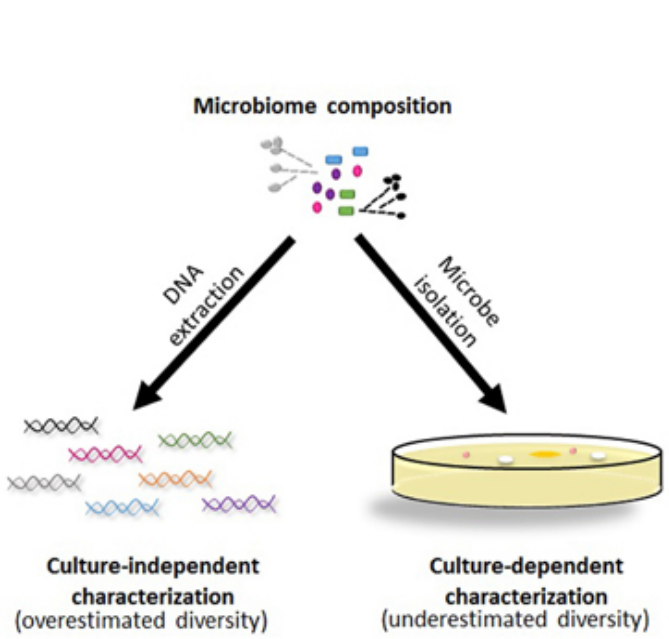
Impact on local communities ?

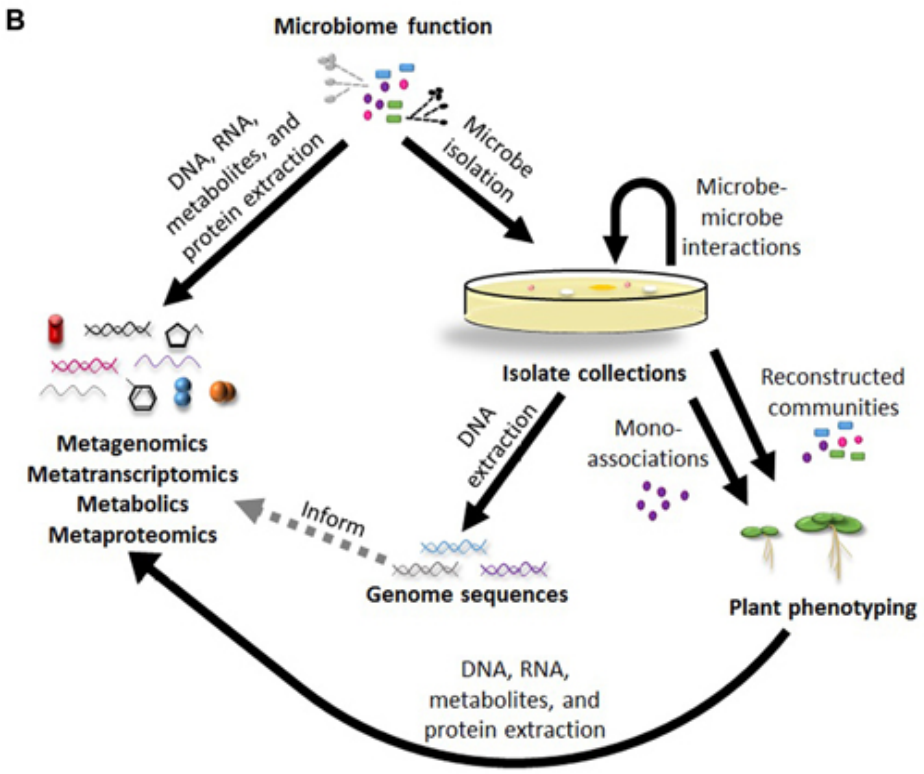
Could the introduced microbe spread on other crops…

- Adapted to crops (specific) & agricultural practices
- Easy production – reasonable cost – shelf life
- Registration
- ABS/Nagoya protocol

Scientific challenges

Knowing the players – knowing their functions





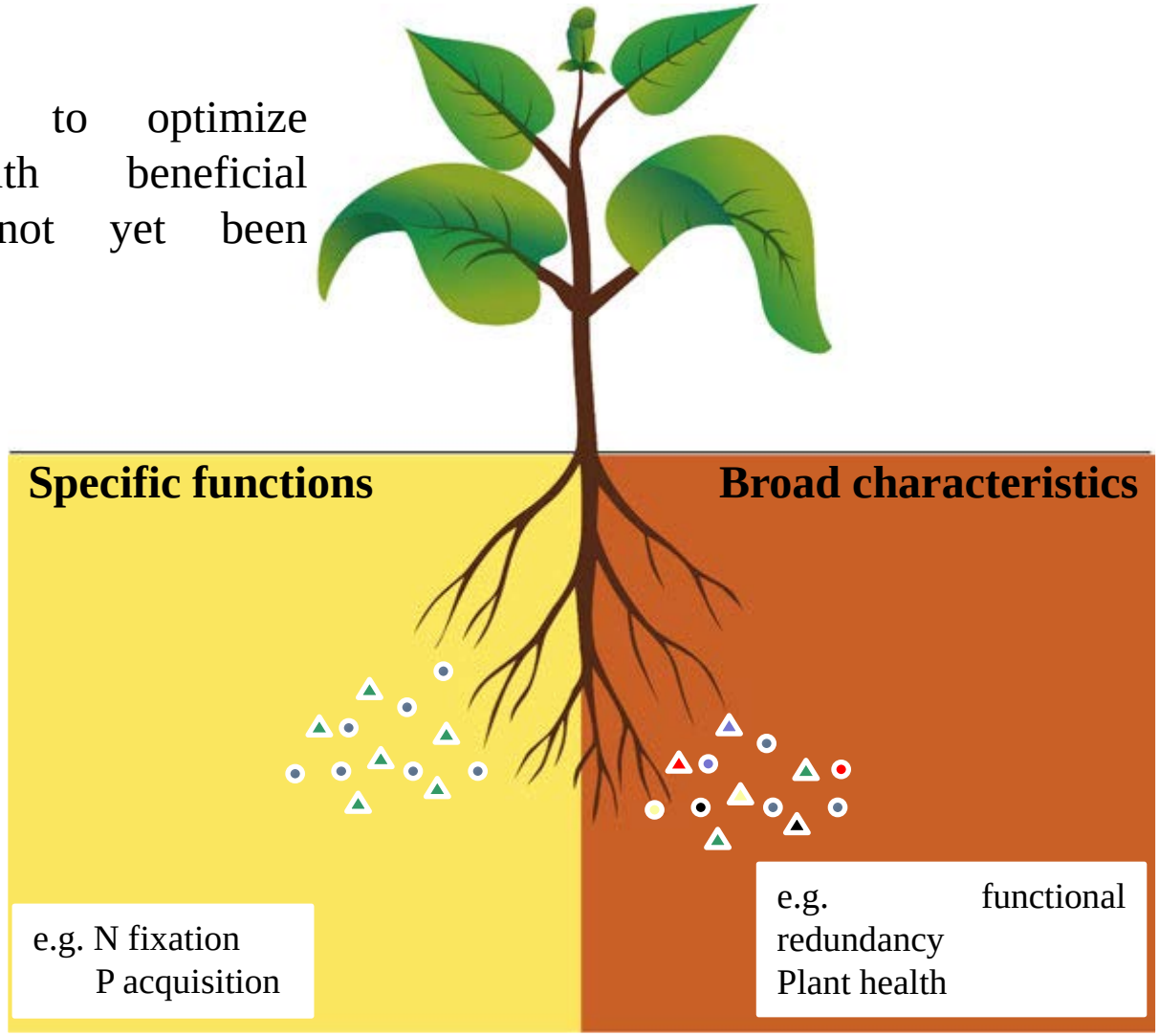
(Lebeis, Frontier in Plant Science, 2014)

Knowing the players – knowing their functions

- Genome sequencing of all major European plant pathogens
- Inventory of symbiotic and other beneficial micro-organisms in the rhizosphere.
- Inventory and exploitation of molecules released by microbes into the soil and atmosphere.
- Development of cropping systems/management practices that takes into consideration beneficial microbes.

Breeding for optimal interaction

Breeding plants to optimize interactions with beneficial microbes has not yet been attempted.



(from Bakker et al., Plant and soil (2012)

Moving forward

Invest in internationally-concerted research

- Microbiologists
- Agronomists
- Breeders
- Soil scientists
- companies

Moving from lab to the field

- Pilot projects
- Field trials

Take one grand challenge

- Fully-characterize microbiome of a crop
- Genome sequencing of all major European plant pathogens (and major BCA's)!

(American Academy of Microbiology, 2012)

MANY THANKS FOR YOUR ATTENTION