Breeding durum wheat for a sustainable future will need to exploit its genotype-specific differential interactions with plant-probiotic micro-organisms

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA

Marco Bosco & Christine Picard

DiSTA-Microbiology, *Alma Mater Studiorum* – Università di Bologna, Viale Fanin 42, Bologna 40127, Italy - marco.bosco@unibo.it

460 million years ago, plants colonized terrestrial environments thanks to the mycorrhizal symbioses (Pirozynski & Malloch, 1975; Redecker et al., 2000). Today, the most part of plants are not yet free from those and other **co-evolved rhizosphere mutualisms**. In fact, in natural environments, plants health & the uptake of nutrients by roots is still regulated by the activities of beneficial rhizospheric micro-organisms (see table on the right), such as the group of plant-growth-promoting rhizobacteria (PGPR) & the arbuscular mycorrhizal fungi (AMF). Recently, they were grouped under the common term "**plant-probiotic" micro-organisms**, or PPM (Haas & Keel, 2003; Picard & Bosco, 2008).

Plant-probiotic activities

Direct:
provision of bioavailable phosphorus, iron, microelements, nitrogen fixation from air,
improvement of water uptake,
synthesis of plant hormones.

Indirect:
synthesis of antimicrobial & pesticide compounds,
fungal cell-wall lysing enzymes;
root surface colonization, heavy metals fixation,
soil structure improvement.

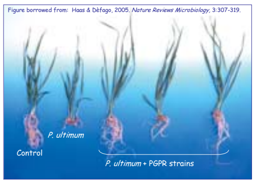
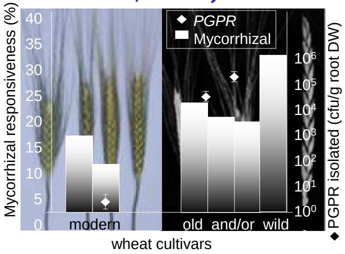


Figure borrowed from: Haas & Défago, 2005. *Nature Reviews Microbiology*, 3:307-319.

From literature reviews, it is now easy to understand how mechanisms other than host resistance likely contribute to plant tolerance towards soilborne pathogens (e.g. *Gaeumannomyces graminis*, *Pythium* spp., *Rhizoctonia* spp. and many *Fusarium* spp.). For example, natural genotypes and some current varieties stimulate and support specific groups of **indigenous plant-probiotics** as the **first line of defense** against soil borne pathogens (Haas & Défago, 2005; Cook, 2006).

However, modern cultivated varieties showed a generally lower capacity to sustain rhizosphere interactions with naturally occurring plant-probiotics, than varieties developed before year 1950. As an explanation, it has been proposed that recent breeding work, done under high-input conditions, may have resulted in a selection against **probiotics-competent plant genotypes**, *i.e.* those that responded well to plant-probiotics (for review, Wissuwa *et al.*, 2008). This was likely due to the higher carbon cost that plants had to pay to PPM, in order to obtain soluble nutrients from insoluble compounds and indirect protection against soilborne pathogens, pests and weeds.



Novel approaches in plant breeding: plant-probiotic related traits

Such loss in probiotics-competence is probably one of the explanations for the difficulty to use the present elite varieties as the biolological pool for selecting new, higly desirable, **sustainable varieties**, *i.e.* those able to use more efficiently the increasingly costly agrochemicals, water and to raise the production in the poorer soils. So, the main **present-day challenge** tends to shift towards the improvement of crops by pre-selecting lines on their ability to rely productivity, quality and health on the positive interactions with plant-probiotics.

As plant-PPM interactions mostly happen **below-ground,** it results very difficult to use traditional breeding schemes, based on the evaluation of thousands of segregating progenies. So, the re-introduction of **plant-probiotic traits** would take great advantage from the application of molecular tools, especially those used in **marker-assisted selections**: few experimental examples already exist, enough to demonstrate that the approach does work (see Wissuwa *et al.*, 2008).

Sustainable ~~Traditional~~ Breeding

↓	↓
rhizosphere-related plant traits	traditional plant traits
↓	↓
indirect enhancement of plant nutrition, health	direct enhancement of plant nutrition, health

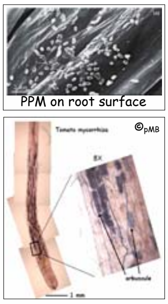
↓ ↓

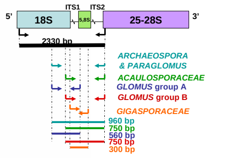
PPM-friendly future crop variety

Tools for early selection of probiotics-competent durum wheath genotypes

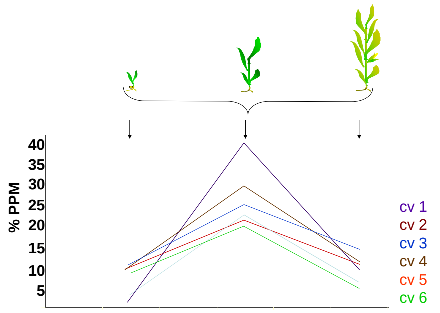
In order to contribute to an efficient set-up of breeding programs for better durum wheat-PPM interactions, we are developing tools for the **detection** of plant genotypes best interacting with selected PPM. Here we show two examples of an **interdisciplinary** (*breeding + microbial ecology*) **research**, recently performed **in low-input conditions**.

Line	Taxonomic diversity of AMF	Resistance to nematode	Yield / plant (g FW)
A	1	-	582.1 d
B	1	-	938.7 cd
C	2	+	1068.1 bc
D	2	+/-	1152.6 bc
E	2	+	1215.1 abc
F	2	+/-	1243.2 abc
G	2	+/-	1267.2 abc
H	2	+/-	1410.4 abc
I	3	++	1510.4 ab
J	3	++	1675.3 a





Among 10 new lines of tomato evaluated in field conditions, the most yielding and healthy showed a more articolated reply to PCR markers for arbuscular mycorrhizal fungi (Picard *et al.*, 2007).



Among 6 maize cultivars evaluated in laboratory conditions, the best performant showed a higher reply to PCR markers specific for biocontrol agents & arbuscular mycorrhizal fungi (*Picard et al.*, 2008).

<u>Conclusion</u>: in both cases, the genotype-specific differential interactions with plant-probiotics were easily detectable by PCR at an early stage (flowering). Thus, it is not necessary to maintain the plants until the maturity to select for plant-probiotic traits. And it is possible to select genotypes in laboratory/greenhouse tests.

* Cook RJ (2006) Toward cropping systems that enhance productivity and sustainability. *Proceedings of the National Academy of Sciences USA*, 103:18389-18394.
* Haas D, Dèfago G (2005) Biological control of soil-borne pathogens by fluorescent pseudomonas. *Nature Reviews Microbiology*, 3:307-319.
* Haas D, Keel C (2003) Regulation of antibiotic production in root-colonizing *Peudomonas* spp. and relevance for biological control of plant disease. *Annu Rev Phytopathol*, 41:117-153.
* Picard C, Bosco M (2008) Genotypic and phenotypic diversity in populations of plant-probiotic *Pseudomonas* spp. colonizing roots. *Naturwissenschaften*, 95:1-16.
* Picard C, Baruffa E, Bosco M (2008) Enrichment and diversity of plant-probiotic micro-organisms in the rhizosphere of hybrid maize during four growth cycles. *Soil Biology & Biochemistry*, 40: 106-115.
* Picard C, Carriero F, Petrozza A, Zamariola L, Baruffa E, Bosco M (2007) Selecting tomato (*Solanum lycopersycon* L.) lines for mycorrhizal competence: a prerequisite for breeding the plants of the future.In: RHIZOSPHERE 2. Montpellier, 26-31 August 2007.
* Pirozynski D, Malloch DW (1975) The origin of land plants: a matter of mycotrophism. *BioSystems*, 6:153-164.
* Redecker D, Kodner R, Graham LE (2000) Glomalean fungi from the Ordovician. *Science*, 289:1920-1921.
* Wissuwa M, Mazzola M, Picard C (2008) Novel approaches in plant breeding for rhizosphere-related traits. *Plant & Soil*, in press [published on line, July 2008. DOI 10.1007/s11104-008-9693-2].

From Seed to Pasta: the Durum Wheat Chain • Bologna, June 30 - July 3, 2008 • Poster 4.11