A Global Perspective on Genetic Resources of Cactus Pear; an Assett for the Future Sustainability of Semiarid Lands

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Outline..

- Cactus pear, population growth and natural resources
- Cactus pear origin and dispersion
- **GR exploration**

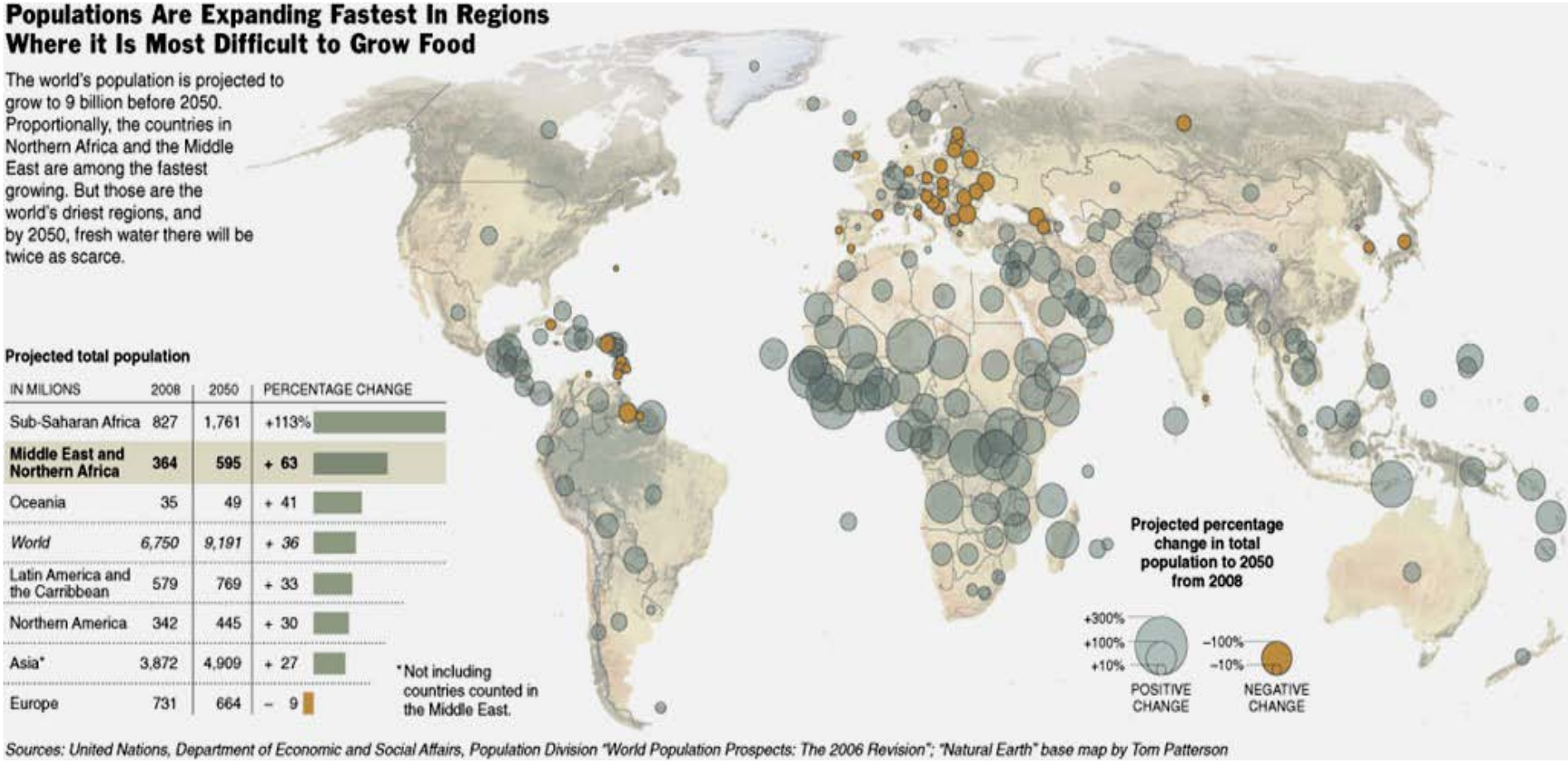
  -Actual pool, where and what is it?

  -What is left to collect?
- **GR documentation**
  - Modern tools to describe and explain variability
- **GR conservation**
  - In situ conservation efforts
  - Ex situ; active germplasm banks
    - Live collections, *In vitro* collections,
    - CENARGEN, a Mexican initiative for long term conservation

Outline …

- GR utilization
  - Conservation linked to utilization
- GR enhancement
  - Breeding goals
  - Breeding achievements
- Towards a sustainable utilization of CP
  - Generation of new varieties in Mexico, Italy and Brazil
  - Countries with naturalized stocks
  - Emergent countries

Cactus pear, population and food production



Cactus pear origin and dispersion

GR exploration ….Actual pool where and what is it North East Africa

- Tigray, a highland region shared by Ethiopia and Eritrea hosts the densest naturalized stocks in Africa.
- Originated from domesticated cactus pear likely from Italy
- Likely spineless forms reverted back to spiny in the wild
- Explored and described

- **Valuable as source of tolerance to drougth and shallow rocky soils.**
- **Quality needs improvement**

Near East and North Africa

•Turkey, Jordan, Syria Israel and other countries have small areas of naturalized cactus pear mostly genotypes similar to the spiny yellow pulp found in NE Africa.
•Egypt has small areas of cultivated spineless probably “Gialla”

Tunisia
2 field collections, containing domesticated accesions mostly O. ficus-indica (>48).
The largest cultivated area in
t Africa 0.5 M Ha
ld collection of wild
ntias

South Africa

42 ? Fruit and forage cultivars
Supported by complete phenologycal, fruit and forage production
& animal utilization studies

Unique collection of Burbank´s “improved” varieties

Cactus pear GRs in Brazil

- North East Brazil, semiarid tropical, unique agroclimatic setting.
- “Gigante" ,“Redonda" and “Miúda" (*Nopalea cochenillifera)* commercial varieties.
- 1061 clones from open pollinated Palma Gigante
- 3 small (<100 accessions) Germplasm Banks, PetrolIna-PE, Tacina-PB ,Rio Grande du Norte at EMPARN.
- - 171 clones open pollinated Palma Miúda
- - 159 clones from Universidad Autonoma de Chapingo, México.
- - 17 clones from several countries by CPATSA.
- - 5 clones from Rio Grande do Norte.
- - 4 clones from Petrolina, utilized to produce cochineal dye probable origin, Italy.
- **1417 clones**.

Italy, Sardinia

- Established in 1992, located in Oristano (39° 53’ N). University of Sassari.
- **More than 2200 accessions.**
- Provenances: Italy (Sardinia and Sicily), Argentina, Chile, USA, Canada, France, Morocco, South Africa.

Diversity collected

- *Opuntia* and *Nopalea* sp
- Wild genotypes and ecotypes
- Local varieties
- Variety selections
- Hybrids from open pollination
- Hybrids from controlled crosses and embryoculture

MEXICO

Use	CRUCEN		IIZD	*INIFAP Gto.	CBTA	INIFAP-SLP
Fresh fruit	357	16	302	97	136	908
Double use	5	-	-	12	-	17
Forage	7	2	3	32	3	47
Vegetable	39	5	30	7	3	86
Triple use	2	----	---	---	----	2
Not reported (N.D)	---	23	---	5	---	28
Animal feed	----	---	---	29	---	29
Ornamental	----	---	---	4	---	4
Condiment	---	----	----	15	---	15
Total	**410**	**46**	**335**	**201**	**142**	**1021**

INIFAP Gto. also maintains a working collections containing; Segregant populations age 12 to 1 yr old (2400), selections (20) and hybrid seeds.

MEXICO INIFAP´s Breeding collection

- >200 accessions of fruit,forage and vegetable.
- >2500 individual plants derived from controlled crosses.
  - Hybrids, self-pollinated, and backcrosses.
  - Ranging from 12 to 1 year old.
- seeds and seedlings from 47 controlled crosses conducted in 2010.
- In-vitro samples of 10 commercial varieties.

GR conservation *Ex situ* conservation efforts…

NATIONAL OPUNTIA REPOSITORY

FIELD COLLECTION CONTAINING 410 ACCESSIONS OF DOMESTICATED CACTUS PEARS

➢**To protect the national wealth Opuntia. To promote and conduct research on Opuntia germplasm. To support conservation and utilization, to provide reference material and data for legal rights**

What is left to collect?

- Wild relatives and related taxa, collect based on estimated value of the resource for use.
- For specific use and valuable traits, or as adaptation strategies to offer site-specific solutions.
  - Fill taxonomic, geographic, or trait gaps in current collections
  - Promote exchange among existing collections
  - Protect populations subjected to habitat destruction and climate change.
- To ensure future collecting is more efficient and effective:
  - -geo-referencing and spatial analysis prior to collecting
  - -promote collaboration between genebanks and breeder

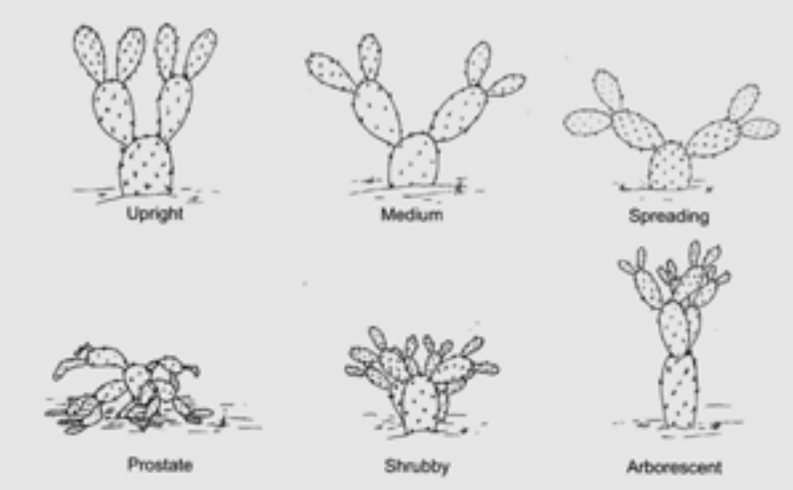
GRs Documentation…

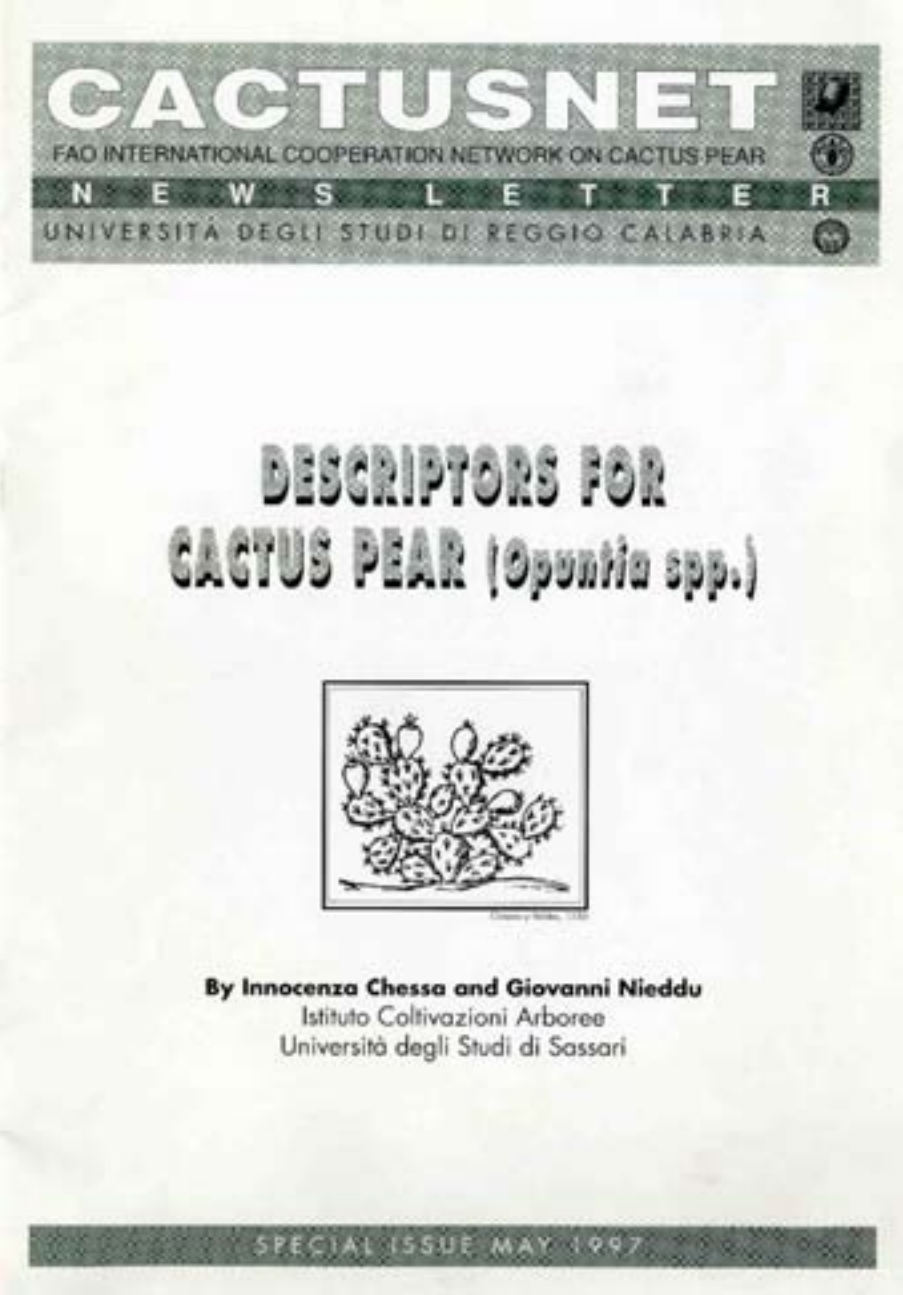
Available descriptors and catalogues

Based on morphology:

Standard Descriptors list

★	7.1.5	**Habitus**	
		1	Upright
		2	Medium
		3	Spreading
		4	Prostrate
		5	Shrubby
		6	Arborescent





Manual Gráfico para la Descripción Varietal del Nopal Tunero y Xoconostle (*Opuntia* spp.)

SECRETARÍA DE AGRICULTURA, GANADERÍA, DESARROLLO RURAL, PESCA Y ALIMENTACIÓN | SAGARPA

SNICS
Sistema Nacional de Inspección y Certificación de Semillas

RED NOPAL

Documentation.....
Book on Mexican Commercial varieties Gallegos-Vazquez et al..... in Press)

REYNA
Opuntia albicarpa

BURRONA
Opuntia albicarpa

MILPA ALTA
Opuntia ficus-indica

CRISTALINA
Opuntia albicarpa

ROJO PELÓN
Opuntia ficus-indica

R. SAN MARTÍN
Opuntia megacantha

VILLANUEVA
O. albicarpa

MONTESA
O. megacantha

PICO CHULO
O. megacantha

GAVIA
Opuntia albicarpa

TORREOJA
Opuntia megacantha

AMARILLA PLÁTANO
Opuntia megacantha

ROJO VIGOR
Opuntia ficus-indica

ROJO LIRIO
Opuntia megacantha

NARANJÓN LEGÍTIMO
Opuntia albicarpa

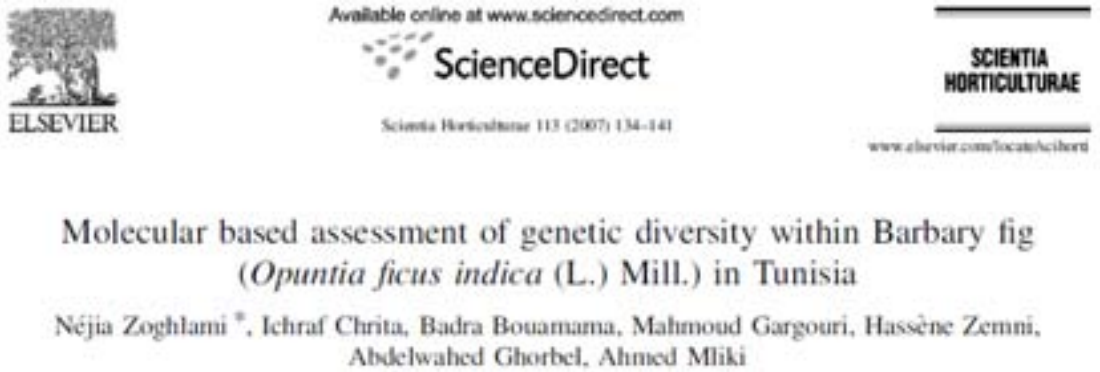
Characterization and evaluation

Tools to describe and explain variability....

Based on molecular traits: molecular markers application
Starting from **Isozymes** (Chessa I. et al., 1997; Uzun, 1997).

RAPD were successfully applied to:

- verify the somatic origin within some Mexican accessions (Mondragon, 1999)
- identify cultivars and recognize duplicate accessions in collections (Wang et al., 1998)
- characterize the Germplasm Bank of the FAUANL (Garcia-Zambrano et al., 2006)
- elucidate the hybrid origin of Opuntia species (Griffith, 2003)



AFLP have been applied to:

- differentiate Opuntia species, investigate genetic relationships among different species, verify the hypothetical identity of *O. ficus-indica* and *O. megacantha* (Labra et al., 2003)
- characterize the South African genetic resources (Mashope et al., 2006)
- estimate genetic diversity in cactus pear within the Germplasm Bank of FAUANL (Garcia-Zambrano EA et al., 2009)

American Journal of Botany 91(11): 1915–1921. 2004.

THE ORIGINS OF AN IMPORTANT CACTUS CROP, *OPUNTIA FICUS-INDICA* (CACTACEAE): NEW MOLECULAR EVIDENCE[1]

M. PATRICK GRIFFITH[2]

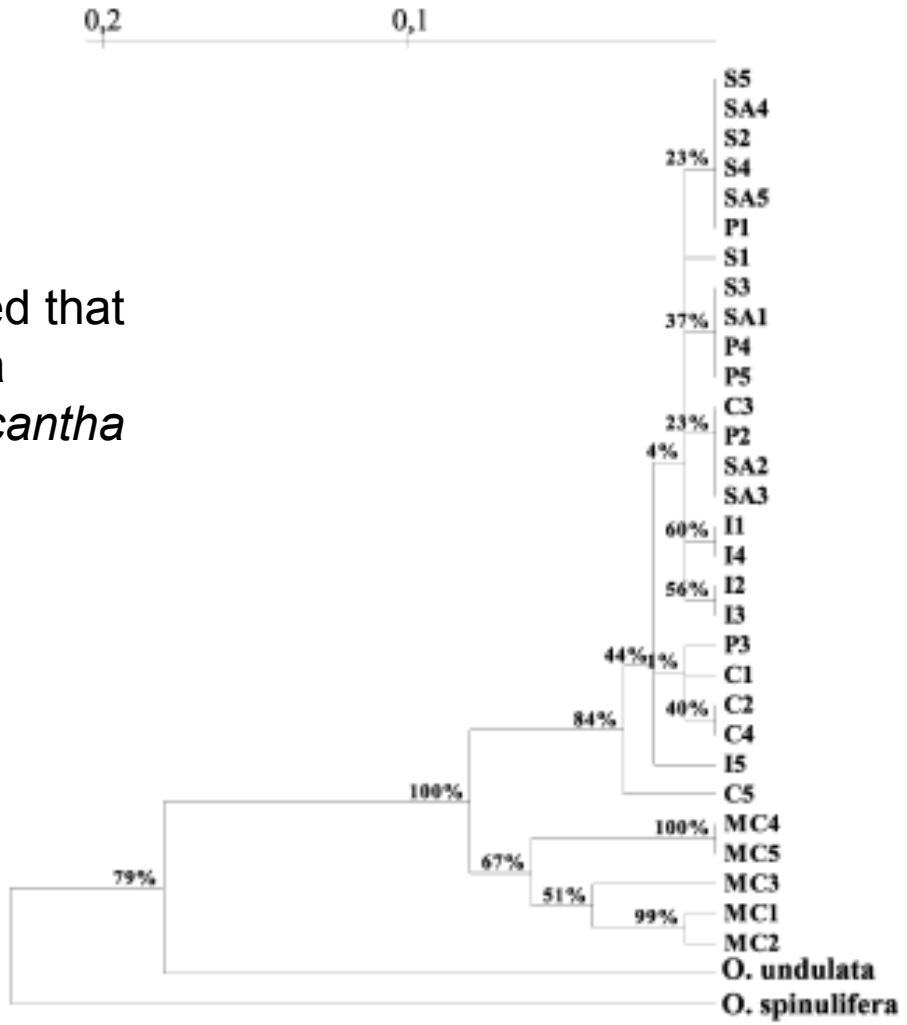
Origin of *O. ficus-indica* is investigated through the use of Bayesian phylogenetic analyses of nrITS DNA sequences:

- *O. ficus-indica* is a close relative of a group of arborescent, fleshy-fruited prickly pears from central and southern Mexico;
- the center of domestication is in central Mexico;
- polyphyletic origin of *O. ficus-indica*

Genetic relationships in *Opuntia* Mill. genus (Cactaceae) detected by molecular marker

Massimo Labra [a,1,*], F. Grassi [b,1], M. Bardini [b], S. Imazio [b], A. Guiggi [c], S. Citterio [a], E. Banfi [c], S. Sgorbati [a]

Using AFLP, Labra et al. (2003) suggested that *O. ficus indica* should be considered as a domesticated form of the spiny *O. megacantha*



Characterization and evaluation

Microsatellites isolation and application;
Microsatellites analysis evidenced on the Galapagos endemic *Opuntia* (*O. echios var. echios and var. gigantea)* the high morphological, but low genetic differentiation (QST[FST), as evidence for divergent selection and adaptation to local environments

Biological Journal of the Linnean Society, 2009, 96, 451–461. With 4 figures

Galápagos' *Opuntia* (prickly pear) cacti: extensive morphological diversity, low genetic variability

PHILIPPE HELSEN[1]*, ROBERT A. BROWNE[2], DAVID J. ANDERSON[2], PETER VERDYCK[1] and STEFAN VAN DONGEN[1]

Helsen et al. 2009 highlighted that the current taxonomic differentiation between these taxa was not supported by molecular data.

Plant Syst Evol (2009) 279:1–10
DOI 10.1007/s00606-008-0064-5

ORIGINAL ARTICLE

Low levels of genetic differentiation between *Opuntia echios* varieties on Santa Cruz (Galapagos)

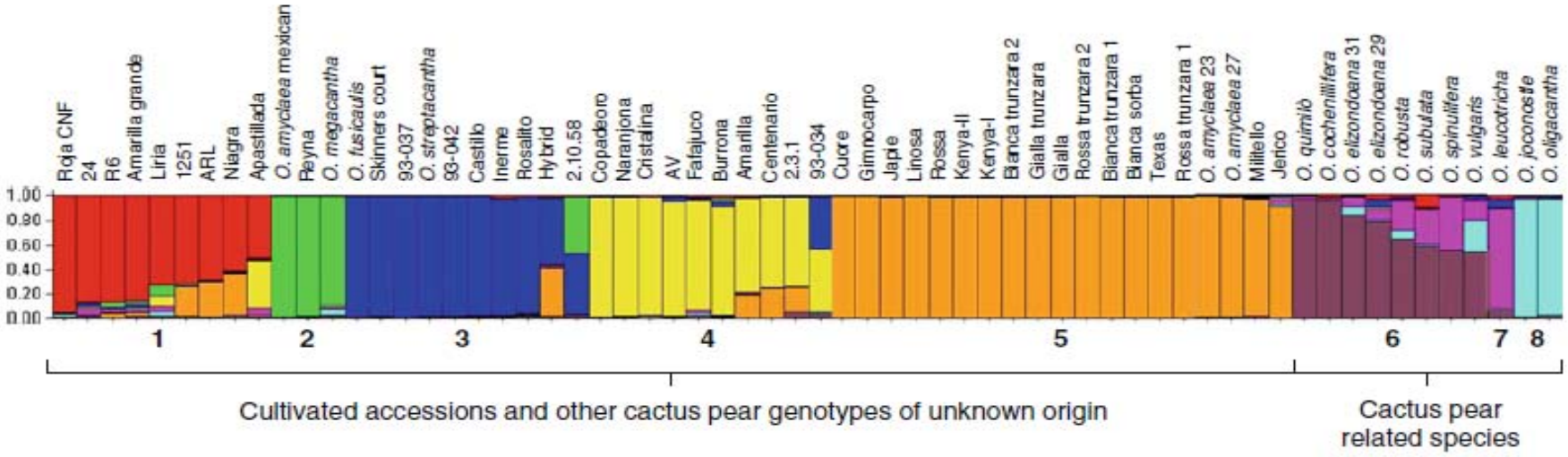
P. Helsen · P. Verdyck · A. Tye · S. Van Dongen

Microsatellite markers help to assess genetic diversity among *Opuntia ficus indica* cultivated genotypes and their relation with related species

Marco Caruso · Sergio Currò · Giuseppina Las Casas · Stefano La Malfa · Alessandra Gentile

Plant Syst Evol
DOI 10.1007/s00606-010-0351-9

The Griffith hypothesis considering *O. ficus indica* as a group of multiple unrelated clones derived from different parental species and selected for common agronomical features is also supported by Caruso et al., 2010 by means of microsatellites



Characterization and evaluation…

-A new set of microsatellites markers, 5 out of ten showing high level of polimorphism, were developed and applied to characterize the germplasm collection hosted by the University of Sassari (Erre et al., in press)

Polymorphic microsatellite DNA markers in *Opuntia* spp. collections (Chessa et al., this congress)

•The high levels of genetic variability between species and the medium levels of differentiation between cultivated accessions were recorded.

•The level of polymorphism and the relatively high number of alleles detected suggest that these markers can be used for both inter and intra-specific studies

Molecular characterization of cactus pears from Queretaro Mexico based on internal transcribed spacer sequences (ITS). (de Lyra et al.,this congress)

Characterization and evaluation

Molecular markers contribution to GR management

Ex situ maintenance:

Sampling, management , development of 'core' collections, utilization of genetic diversity.

In situ and *'on farm'* preservation:

Recognition of the most representative populations within the 'gene pool'
Identification of the most suitable strategies for management and use.

To analyze cactus pear genetic diversity for different purposes, such as variety selection, genotypes identification and certification

GR conservation long term efforts:
In Vitro, seed cold storage

inifap
Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

CNRG
Centro Nacional de Recursos Genéticos

National Center for Genetic Resources
Tepatitlan, Jal. Mexico
Opening Nov 2010

GR conservation
In situ conservation efforts

- Easy to justify for ecologycal and scientific reasons but:
  - Difficult to materialize, costly, long term endeavour
  - Social and political issue
  - None registered in Mexico

Conservation linked to uses

- Considering its biological, agricultural and socio-economic value
- Cultivation with low input benefits environment and favors conservation
- Potential source of innovation for a sustainable agriculture
  - ✓new crop option
- Opuntias are multiple use plants intrinsically resistant to drylands conditions
- They contribute to the conservation of traditional farming systems and their natural values, and the maintenance of the rural landscape

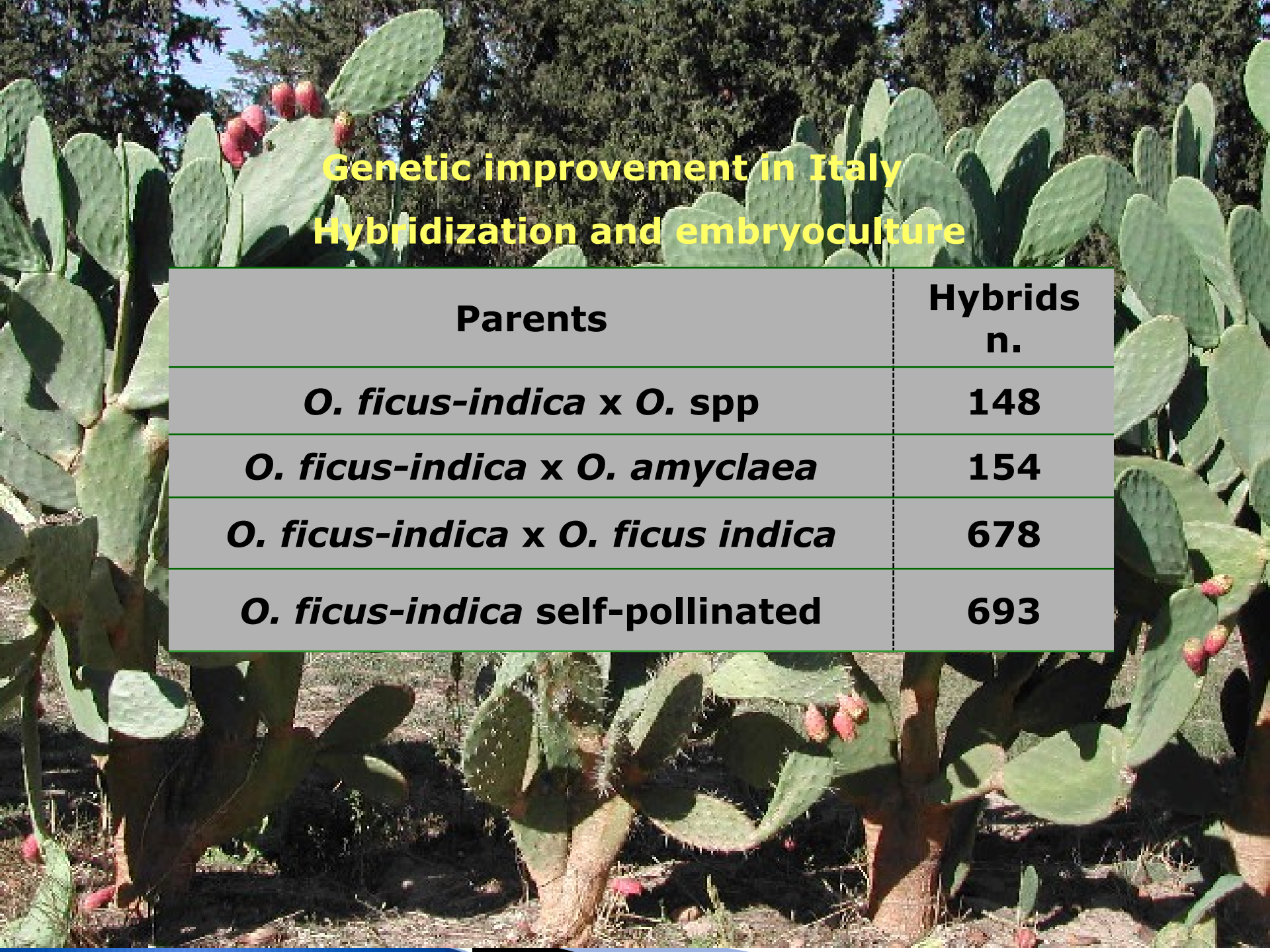
Genetic improvement in Mexico

Concentrated in the Central Region

Started in 1995
Aimed to fulfill the demands of:
•improved fruit quality
•extended production season
•tolerance to pests and diseases

•Focussed on Intermediate products and the development of multipurpose varieties to improve the output and benefit
Reduce the impact of biological complexity of the Opuntias

- •First products (In registration process presented at his congress)
- •Starting 2010 one generation/year



Genetic improvement in Italy

Hybridization and embryoculture

Parents	Hybrids n.
O. ficus-indica x *O.* spp	148
O. ficus-indica x *O. amyclaea*	154
O. ficus-indica x *O. ficus indica*	678
O. ficus-indica self-pollinated	693

Breeding goals

FRUIT PRODUCTION

Low seed content
Spineless pads
Less glochids
Large colorful fruits (peel and flesh)
Juicy fruits
Tolerance to handling and packing

Frost tolerance
Pests and diseases
Off-season production

Multiple use cultivars

FORAGE PRODUCTION

Improve nutritional content
Frost tolerance
Spineless cladodes
High productivity and quick recovery after pruning
Frost tolerance
Wider adaptability ,specially to tropical dry & hot
Adapted to intensive production systems
Pest and disease tolerance

GR enhancement....

Italian selections for fruit production

Selection	Shape	Size	Peel colour
White peel group			
BB	ovoid	large	light yellow
M3	ovoid	large	light green
BSC	ovoid	small	light green
BSS	elliptic	medium	light yellow
Yellow peel group			
GB	elliptic	medium	orange
M1	ovoid	small	dark yellow
GS	ovoid	medium	dark yellow
GSC	ovoid	medium	orange
Red peel group			
RC	ovoid	medium	red
M2	ovoid	medium	purple
RSC	ovoid	medium	purple
RSS	ovoid	large	purple

Breeding achievements
New cultivars …

Mexican
Cvs.
“Juanita”

“Orelha de Elefante Mexicana”
Brazil IPA

USA D Arrigo Bros,
Signature Series Cactus Pears
~Sweet **Emerald** ~Sweet **Purple**
~Sweet **Crimson** ~Sweet **Sunset**

“Vine

Towards a sustainable utilization of CP

- New varieties are and will be the axis of any sustainable production system.
- Mexico, Italy and Brazil.
  - GR availability, expertise and suitable environment. Conduct breeding potential collaboration with other CACTUSNET countries if funds available.
- Countries with naturalized stocks.
  - Start selection and assessment, propagation of outstanding genotypes, keeping genetic identity and phytosanitary standards (GIPS).
- Other countries new to cactus pear cultivation.
  - Introduce the largest possible variability of improved cultivars before promote cultivation on extensive areas. Conduct medium term evaluation projects. Propagate following strict GIPS.