A Review of the Angular Leaf Spot Disease of Common Bean in Latin America and Africa and Implications for Improved Disease Management

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Angular Leaf Spot (ALS) of Common Bean

ALS Symptoms on Pods, Stems
South Africa, 2015

Main Losses Caused by ALS

- **Premature and Severe defoliation**
- **Severe yield losses**

ALS Severe Defoliation

Geographic Distribution of ALS in the World

Reported in about 80 countries

- The Americas, including the USA and Canada
- Africa, countries in Eastern, Southern and Central African
- Asia
- Australia
- Europe

Economic Importance of ALS

- A recurrent and often severe disease of dry beans
- Particularly important in
  - Latin America:
    - Many countries; especially in Brazil and Central America
  - **Africa**
    - 18 countries
    - Malawi, Great Lakes Region, Uganda
    - Humid southern African Countries

Causal Agent of the ALS Disease
Pseudocercospora griseola (PG)

- PG first reported in Italy, 1878
- Previously named:
  - *Isariopsis griseola*
  - *Phaeoisariopsis griseola*
- A fungal pathogen with unknown sexual stage

Spores of *Pseudocercospora griseola*

Fruiting Structures (Conidiophores) holding spores

Crous et al. Stud Mycol. Vol. 55, 2006.

ALS Disease Before 1980

- Minor importance in Latin America and Africa
- Moreover
  - Very little was known about the diversity of PG

Studies of PG in the 1950s

- Some studies reported that PG was variable in virulence
- Races of PG were reported:
  - Brock, 1951
  - Marin-Villegas, 1959
- **But these results were not conclusive**
- Authors did not use either:
  - Single spore isolates
  - Pure differential cultivars

Conclusive Evidence of Virulence Diversity of ALS Pathogen: *Isariopsis griseola*

- **Reported in 1979**
  - Alvarez Ayala and Schwartz, BIC, Vol. 22, 1979
  - Used five differential cultivars and five single-spore isolates

Bean Cultivar	1 ECU San Franc	1 COL Narino	2 COL Cauca	3 COL Valle	4 COL Nar P. coc
Caraota 260	R	R	S	S	S
Alabama 1	R	R	S	R	R
Red Kidney	S	S	S	S	R
Ica Duva	S	S	S	S	R
Cauca 27	R	R	S	R	R

Four races identified

In the 1980s New Reports of increased ALS severity

- In Latin America and Africa
- New virulence diversity studies of PG followed

ALS Virulence Studies in 1980s

- **Buruchara,** PhD Thesis, 1983
  - Characterized 21 isolates of *Isariopsis griseola*
  - Used six Differential cultivars
  - Seven races reported
- **Correa & Saettler,** 1986, Phytopathology
  - Phenotyped 70 isolates of *Isariopsis griseola*
  - Used eight differential cultivars
  - Six races reported

Issues with New PG Virulence Diversity Studies

- Each study used a different sets of differential cultivars
- Races of ALS pathogen could not be compared

CIAT - Many studies under greenhouse conditions

- Compared all differentials cultivars used by different authors
- Characterized virulence of PG isolates from:
  - Latin America
  - Africa

CIAT - Studies under Field Conditions

- Compared reactions of Andean and Mesoamerican cultivars in:
  - Colombia
  - Brazil
  - Great Lakes region of Africa

Patterns of Virulence Diversity observed in Greenhouse Studies

- Many different races identified
- Results revealed:
  - Some PG races of were host-specific
  - Infected only Andean cultivars
- Other races were not host-specific

Patterns of Virulence Diversity Observed in Field Studies

- Mesoamerican cultivars were highly resistant in African countries
- Andean beans predominated in these countries
- Andean cultivars highly resistant in Brazil
- Mesoamerican beans predominant in Brazil

Comparing Greenhouse and Field Studies

- Results from field studies corroborated greenhouse studies
- Increasing evidence that PG diversity segregated in two groups
- Results helpful for creation of a more effective set of differentials cultivars to study virulence diversity of PG


Going Forward

New Set of Differential Cultivars Created

- New set included Andean and Mesoamerican differential cultivars
- Initial differential set contained 16 differentials cultivars
- After some experimentation, a smaller set with 12 differentials was created

New Set of Differential Cultivars Created

- Had six Andean and six Mesoamerican differential cultivars
- Adopted binary system used to name races of anthracnose pathogen of common bean: *Colletothrichum lindemuthianum*

New set of Differential Cultivars and Binary System to Characterize races of *Phaeoisariopsis griseola*

1994 CIAT Annual Report - Bean Program

Code	Cultivar ID	Seed Size	Bean Race	Binary Value
A	Don Timoteo	Medium	Chile	1
B	G 11796	Large	Peru	2
C	Bolon Bayo	Large	Peru	4
D	Montcalm	Large	Nueva Granada	8
E	Amendoim	Large	Nueva Granada	16
F	G 5686	Large	Nueva Granada	32
G	Pan 72	Small	Mesoamerica	64
H	G 2858	Medium	Durango	128
I	Flor De Mayo	Small	Jalisco	256
J	Mexico 54	Medium	Jalisco	512
K	BAT 332	Small	Mesoamerica	1024
L	Cornell 49242	Small	Mesoamerica	2048

Characterizing Races of *Phaeoisariopsis griseola* Using 12 Differential Cultivars and the Binary System

	Reaction of Andean and Mesoamerican Differential Bean Cultivars												
	Andean						Mesoamerican						
Differential cultivars	A	B	C	D	E	F	G	H	I	J	K	L	Race
Binary Value	1	2	4	8	16	32	64	128	256	512	1025	2048	
ID of races obtained by adding binary numbers of susceptible differentials													
PG 1 ECD	a	b	c	d	e								31
PG 66 COL	a	b	c	d	e	f							63
PG 17 COL	a	b	c				g	h				l	2247
PG 244 COL	a	b	c	d	e		g	h	i	j		l	3039

1994 CIAT Annual Report - Bean Program

Virulence diversity of *Phaeoisariopsis griseola* in Ecuador and Colombia

	Andean Differential cultivars						Mesoamerican Differentials						
PG Isolate	A	B	C	D	E	F	G	H	I	J	K	L	Race
PG 1 **ECD**	a	b	c	d	e								31
PG 14 COL		b	c	d									14
PG 67 COL	a	b	c	d									15
PG 247 COL		b	c	d	e								30
PG 71 COL	a	b	c	d	e								31
PG 243 COL	a	b	c	d	e								31
PG 248 COL	a	b	c	d	e								31
PG 66 COL	a	b	c	d	e	f							63
PG 3 COL	a	b	c	d	e	f							63
PG 85 COL	a	b	c	d	e	f	g	h	i	j			1023
PG 15 COL	a	b	c				g	h				l	2247
PG 17 COL	a	b	c				g	h				l	2247
PG 37 COL	a	b	c	d	e		g	h	i			l	2557
PG 242 COL	a	b	c	d			g		i	j		l	12895
PG 81 COL	a		c				g	h	i	j		l	3013
PG 44 COL	a	b	c	d	e		g	h	i	j		l	3039
PG 244 COL	a	b	c	d	e		g	h	i	j		l	3039
PG 239 COL	a	b	c	d	e		g	h	i	j		l	3039
PG 254 COL	a	b	c	d	e		g	h	i	j		l	3039
PG 65 COL	a						g	h	i		k	l	3521
PG 32 COL	a	b	c	d	e		g	h	i		k	l	3521
PG 61 COL	a		c	d			g	h	i	j	k	l	4015

Lowercase letters a to l indicate susceptibility of differential cultivar to the specific isolate of P. griseola.

Andean differential genotypes are: A = Don Timoteo, B = G 11796, C = Bolon Bayo, D = Montcalm, E = Amendoin, F = G 5686;

Mesoamerican differential genotypes are: G = Pan 72, H = G 2858, I = Flor de Mayo, J = Mexico 54, K = BAT 332, L = Cornell 49–242.

Characterized 55 PG isolates from Latin America Using New set of differential Cultivars

Country	Isolates	Andean		Mesoamerican	
Country	Isolates	Isolates	Races	Isolates	Races
Ecuador	1	1	1		
Colombia	21	8	5	13	8
Brazil	6			6	6
Bolivia	6			6	3
Costa Rica	7			7	5
Honduras	7			7	6
El Salvador	2			2	2
Guatemala	1			1	1
Mexico	4			4	2

1994 CIAT Annual Report - Bean Program

Characterized 18 PG isolates from Africa Using New set of differential Cultivars

Country	Isolates	Andean		Mesoamerican	
Country	Isolates	**Isolates**	Races	**Isolates**	Races
Malawi	6	**5**	3	**1**	1
South Africa	3	**2**	2	**1**	1
Uganda	7			**7**	4
Rwanda	1			**1**	1
DR Congo	1			**1**	1

1994 CIAT Annual Report - Bean Program

Summary of Virulence Diversity of PG in Latin America

Great virulence diversity found

- 55 Isolates
- Characterized into 31 races

- All PG races segregated into two distinct groups:
  1. Andean
  2. Mesoamerican

Summary of Virulence Diversity of PG in Latin America - 1984

- Andean races were isolated from Large-seeded beans from the Andean gene pool
- Mesoamerican races isolated from beans of Mesoamerican gene pool

Summary of Virulence Diversity of PG in Latin America - 1984

- Increasing evidence suggested virulence diversity of Mesoamerican races was greater than diversity of Andean races
- Association between races with their corresponding gene pool of common bean gene pools suggested parallel micro-evolution (co-evolution)

Summary of Virulence Diversity of PG in Africa

- Small number of isolates
  - 18 Isolates, 11 races
- All races also segregated into two distinct groups of races:
  - 4 Andean
  - 7 Mesoamerican

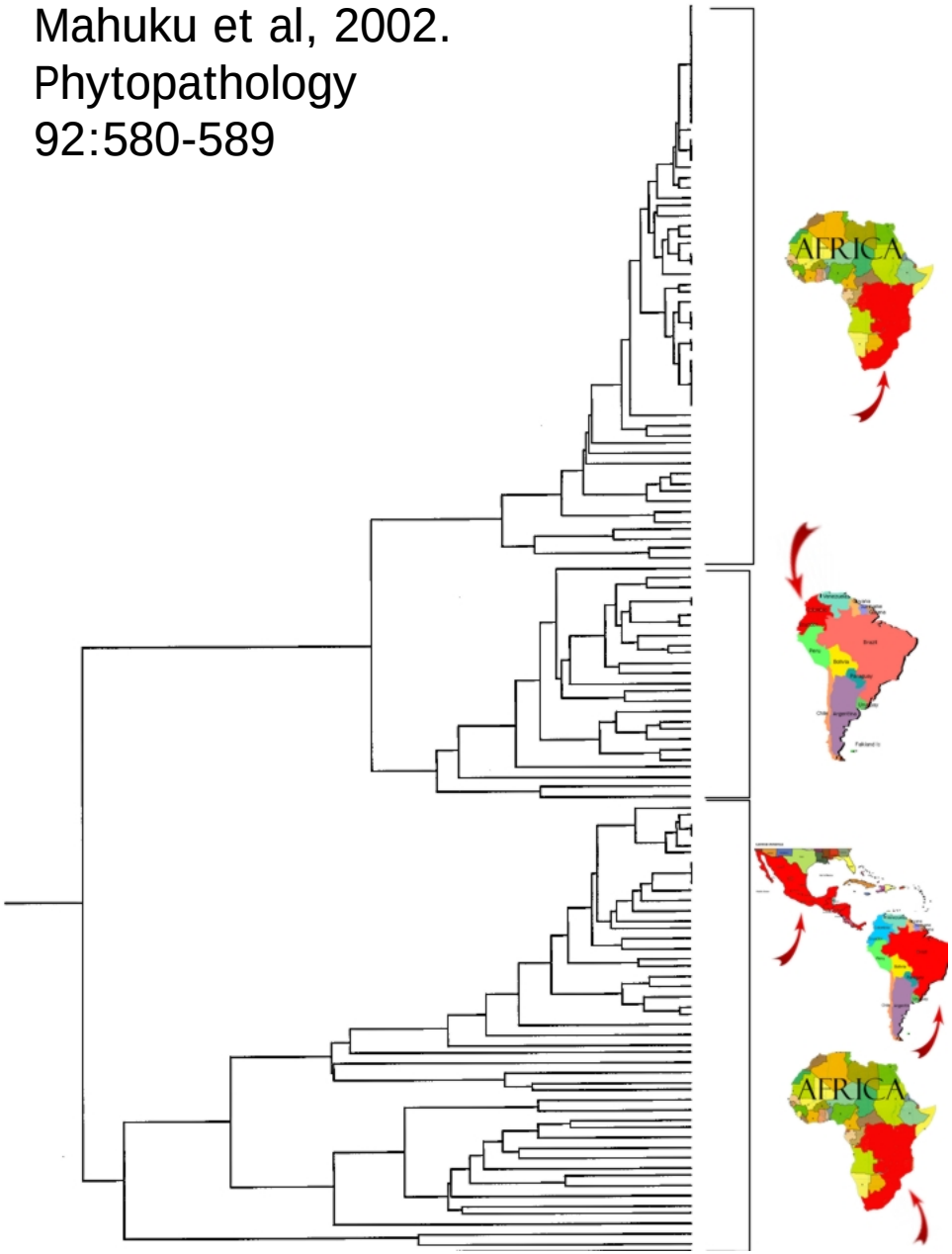
Summary of Virulence Diversity of PG in Africa

- As in Latin America, most races were unique to a location or to a country
- Most races occurring in one country did not occur in another
- Four of 11 races from Africa also present in Latin America
- Greater virulence diversity in Latin America than in Africa

Summary of Virulence Diversity of PG

- Andean races from South America infect only Andean differential cultivars
- Andean races from Africa infect only or mostly Andean differential cultivars
- Mesoamerican races infect both
- Virulence Diversity of PG is greatest in Central America
- This clustering has been confirmed by DNA analysis

Mahuku et al, 2002.
Phytopathology
92:580-589

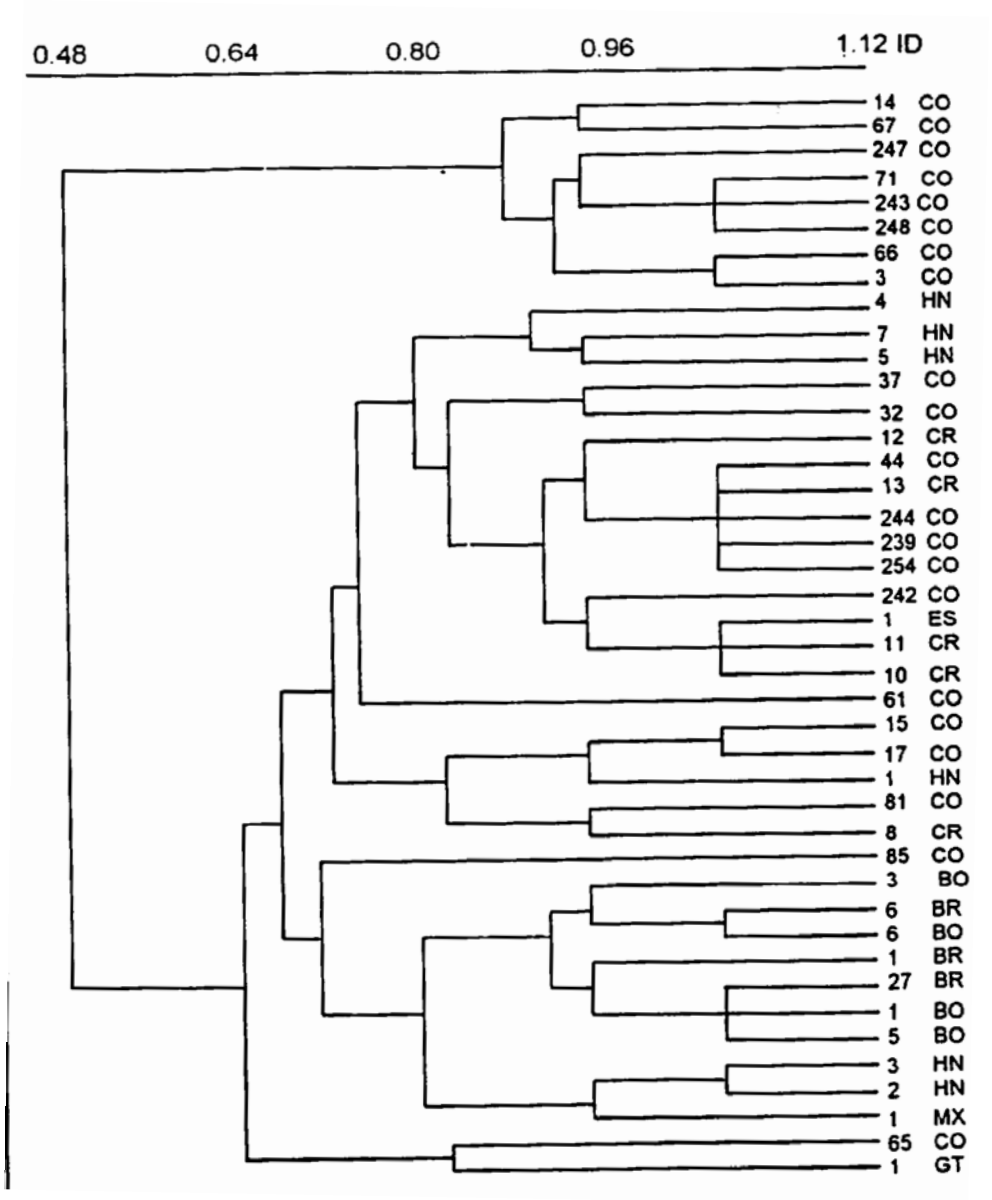


PG isolates segregated into two groups as revealed by RAPD and RAMS DNA markers

Andean isolates from Africa

Andean isolates from South America

Mesoamerican isolates from Latin America and Africa



42 isolates of *Phaeoisariopsis griseola* from Latin America

based on the presence or absence of bands with five RAPD DNA primers

showing the separation of isolates into two large groups:

Andean: eight isolates.
Mesoamerican : 34 isolates

Pastor-Corrales and Jara, *Fitopatologia Colombiana*, Vol. 19, No. 1, 1995.

All in All
This was a Seminal Study

- Same differential set of differential cultivars was adopted later by most ALS researchers
- Lots of comparable virulence diversity studies from 1994 to 2014

New Set of ALS Differential Cultivars Adopted in 1995

- A workshop was organized at CIAT, 1995:
- "The First International Angular Leaf Spot of Common Bean"
- Many attendants from bean-producing countries of Latin America and Africa
- Objective was to standardize methodology for the identification of new races of the ALS pathogen

New System to Characterize Virulence diversity of PG

- ALS workshop in 1995 Adopted:
- New set of six Andean and six Mesoamerican differential cultivars
- A new binary system to name races of PG also was alos adopted

New set of Differential Cultivars and Binary System to Characterize races of *Phaeoisariopsis griseola*

1994 CIAT Annual Report - Bean Program

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F	G 5686	Large	Nueva Granada	32
G	Pan 72	Small	Mesoamerica	1
H	G 2858	Medium	Durango	2
I	Flor De Mayo	Small	Jalisco	4
J	Mexico 54	Medium	Jalisco	8
K	BAT 332	Small	Mesoamerica	16
L	Cornell 49242	Small	Mesoamerica	32

Naming two Andean and two Mesoamerican races of *Phaeoisariopsis griseola* using the binary system

		Bin System	PG 1 ECD	PG 66 COL	PG 32 COL	PG 61 COL
A	Don Timoteo	1	a	a	a	a
B	G 11796	2	b	b	b	
C	Bolon Bayo	4	c	c	c	c
D	Montcalm	8	d	d	d	d
E	Amendoim	16	e	e	e	
F	G 5686	32		f		
			31	**63**	**31**	**13**
G	Pan 72	1			g	g
H	G 2858	2			h	h
I	Flor De Mayo	4			i	i
J	Mexico 54	8				j
K	BAT 332	16			k	k
L	Cornell 49242	32			l	l
			0	**0**	**55**	**63**
Race Nomenclature			**31-0**	**63-0**	**31-55**	**13-63**

Bean Production in Argentina

- 45% Alubia (white)
- 42% Black bean
- 13% others

Angular Leaf Spot

ALS (*Pseudocercospora griseola*)

one of the most important causes of yield losses and seed quality decrease

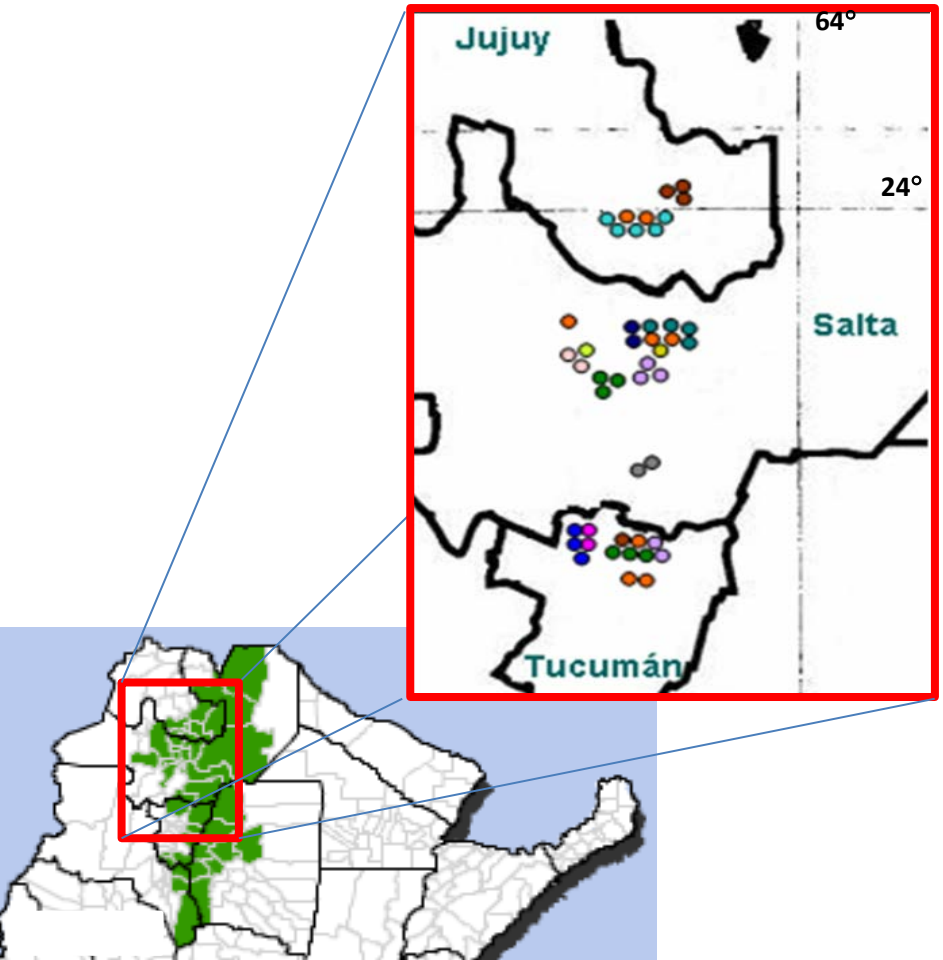
observed sectioned in certain areas

(S of Salta, N and S of Tucumán and the SE of Catamarca)

Mesoamerican and Andean races

Phaeoisariopsis griseola virulence diversity in Argentina

- In NW Argentina 13 races of the ALS pathogen have been identified based on a set of 12 differential cultivars.



- 45 isolates analyzed:

  37 Mesoamerican (10 races)

  8 Andean (3 races)

Andean						Middle American						Race	N of isolates
a	b	c	d	e	f	g	h	i	j	k	l		
1	2	4	8	16	32	1	2	4	8	16	32		
-	+	+	+	-	-	-	-	-	-	-	-	14.0	5
-	+	+	+	+	-	-	-	-	-	-	-	30.0	1
+	+	+	+	+	-	-	-	-	-	-	-	31.0	2
+	+	+	+	+	-	+	+	+	-	-	+	31.39	2
+	+	+	-	-	+	+	+	+	-	-	-	39.7	2
+	+	+	+	+	+	+	+	+	-	-	-	63.7	6
+	+	+	+	+	+	+	+	+	+	-	-	63.15	8
+	+	+	+	+	+	+	+	+	-	+	-	63.23	3
+	+	+	+	+	+	+	+	+	+	+	-	63.31	4
+	+	+	+	+	+	+	+	+	-	-	+	63.39	4
+	+	+	+	+	+	+	+	+	+	-	+	63.47	5
+	+	+	+	+	+	+	+	+	-	+	+	63.55	1
+	+	+	+	+	+	+	+	+	+	+	+	63.63	2

Reaction of 12 differential bean cultivars to inoculation with 45 isolates of *Phaeoisariopsis griseola* in Argentina

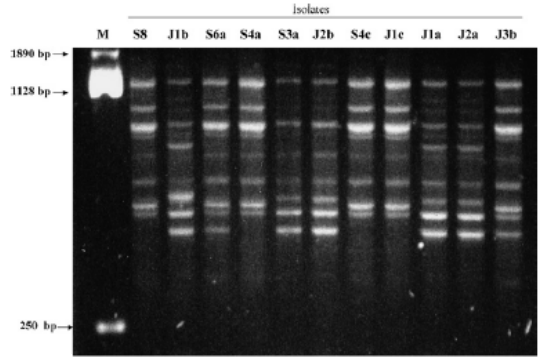
Andean						Mesoamerican						Race	N of isolates
													aislamientos
a	b	c	d	e	f	g	h	i	j	k	l		
1	2	4	8	16	32	1	2	4	8	16	32		
-	+	+	+	-	-	-	-	-	-	-	-	14.0	5
-	+	+	+	+	-	-	-	-	-	-	-	30.0	1
+	+	+	+	+	-	-	-	-	-	-	-	31.0	2
+	+	+	+	+	-	+	+	+	-	-	+	31.39	2
+	+	+	-	-	+	+	+	+	-	-	-	39.7	2
+	+	+	+	+	+	+	+	+	-	-	-	63.7	6
+	+	+	+	+	+	+	+	+	+	-	-	63.15	8
+	+	+	+	+	+	+	+	+	-	+	-	63.23	3
+	+	+	+	+	+	+	+	+	+	+	-	63.31	4
+	+	+	+	+	+	+	+	+	-	-	+	63.39	4
+	+	+	+	+	+	+	+	+	+	-	+	63.47	5
+	+	+	+	+	+	+	+	+	-	+	+	63.55	1
+	+	+	+	+	+	+	+	+	+	+	+	63.63	2

8 Andean isolates (3 races), 37 Mesoamerican isolates (10 races)

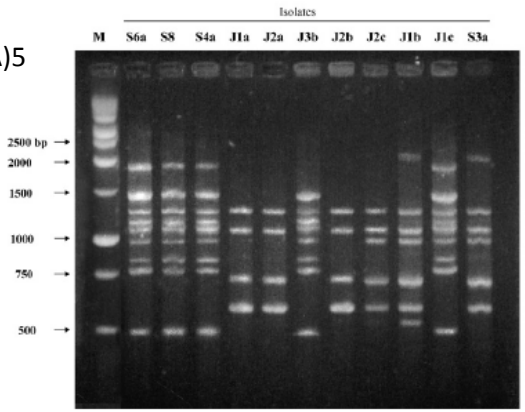
Phaeoisariopsis griseola genetic diversity in Argentina

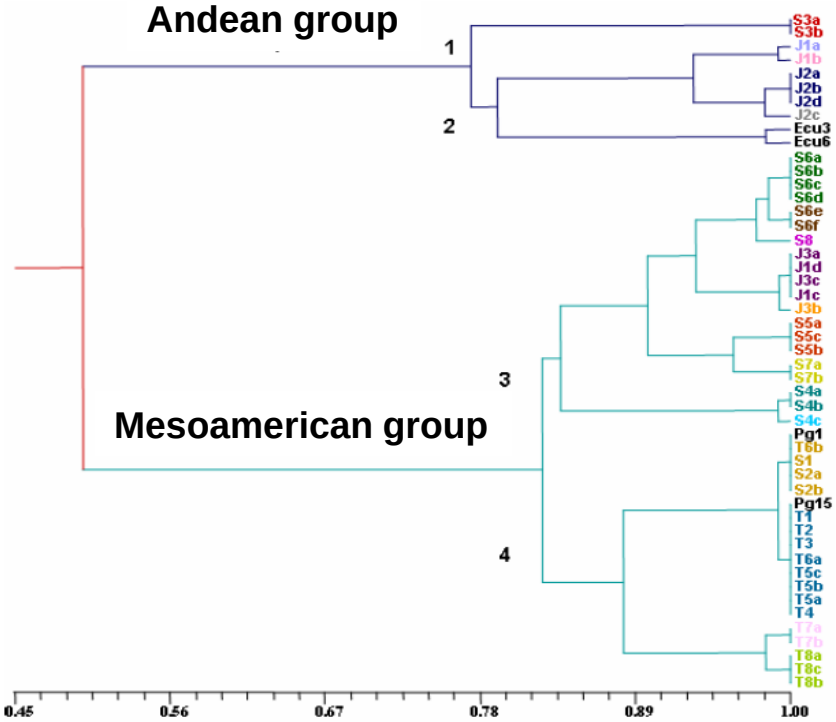
- RAPD + ISSR

RAPD
OPA10



ISSR
GAG(CAA)5





High genetic variability. The Andean isolates significantly differed from the Mesoamerican once.

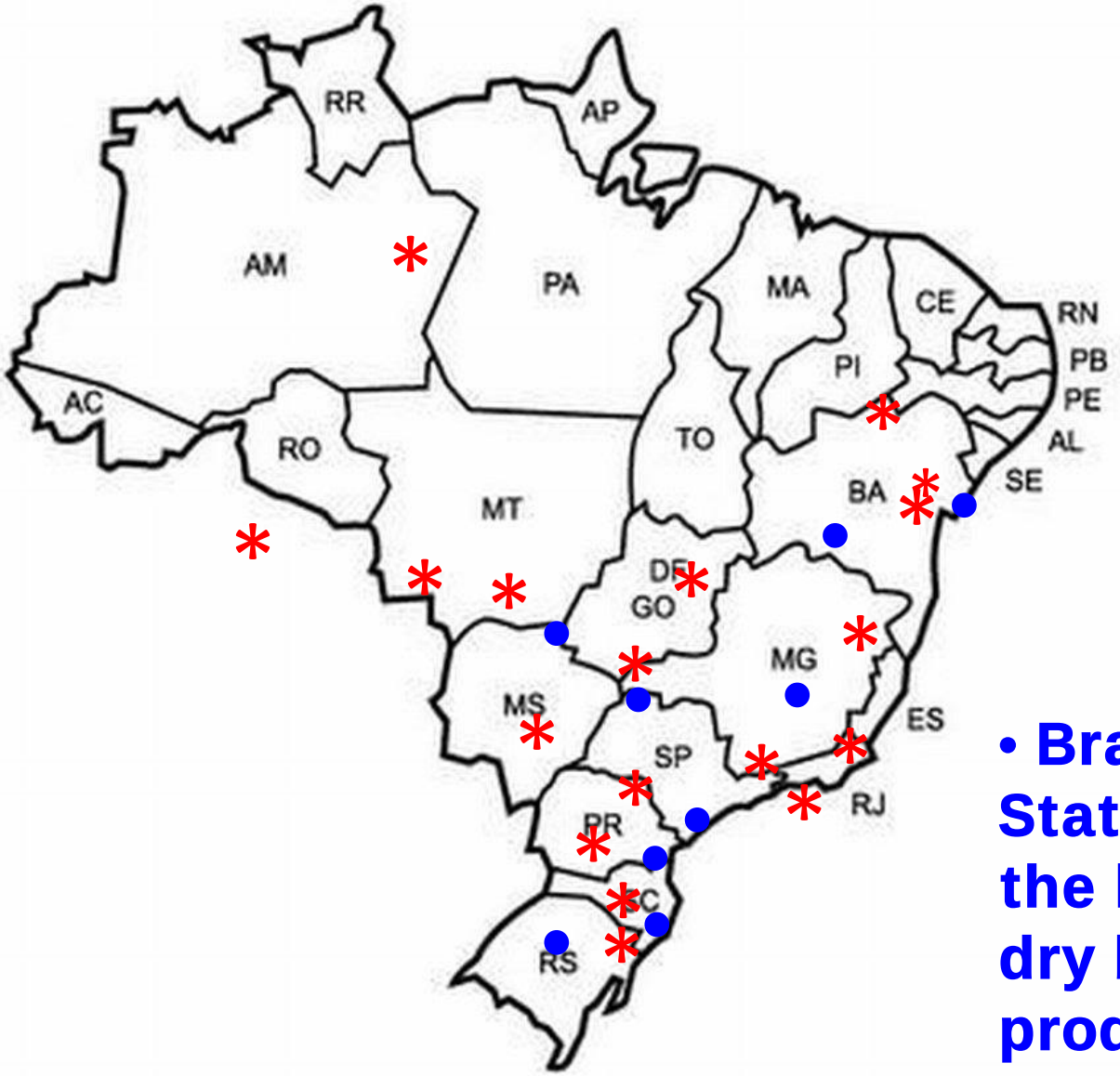
Summary of diversity of *Phaeoisariopsis griseola* in Argentina

- 45 isolates of PG studied
- 8 Andean isolates were virulent only on Andean differential cultivars
- 37 Mesoamerican isolates were virulent on Andean and Mesoamerican differential cultivars
- Diversity based on molecular markers was similar to virulence diversity

ALS in Brazil

- One of the most widespread and important diseases of dry beans in Brazil
- Seed yield Losses as high as 70%
- ALS has been reported occurring in at least in 18 of the 26 states of Brazil

Occurence of ALS in Brazil



- **Brazilian States with the highest dry bean production**

Dry Beans in Brazil

- Small- seeded Mesoamerican beans dominate 90% of the domestic market
- Carioca, black, and mulatinho (cream) - too a lesser extend
- Small amount of medium to large-seeded beans of Andean race sold in small quantities in local market

Thung et al, . 2002. Major dry beans market class and performance of selected large-seeded types. Ann Rep Bean Improv Coop 45: 108-109.

Virulence Diversity studies of *Pseudocercospora griseola* in Brazil

Year	Authors	No Isolates	No Races	Gene Pool
2000	Sartorato et al	42 SC, PR, GO, MG, PB	7	**Mesoamerican**
2001	Nietsche et all	30 MG	13	**Mesoamerican**
2002	Sartorato et al	56 MG	9	**Mesoamerican**
2002	Sartorato et al	51 SC, PR, GO, MG, PB	7	**Mesoamerican**
2004	Sartorato	66 GO	13	**Mesoamerican**
2006	Garcia et al	96 GO	7	**Mesoamerican**
2008	Silva et al	48 MG	10	**Mesoamerican**
2009	Balbi et al	17 MG	12	**Mesoamerican**

Pathogenic variability in *Phaeoisariopsis griseola* from Five Brazilian States

All races are Mesoamerican

Table 1. Reaction of differential cultivars inoculated with 42 isolates of *Phaeoisariopsis griseola*.

Pathotype	Andean beans						Middle American beans						Num of
	1[a]	2	3	4	5	6	7	8	9	10	11	12	Isolates
31-23	+[b]	+	+	+	+	-[c]	+	+	+	-	+	-	1
55-31	+	+	+	-	+	+	+	+	+	+	+	-	1
63-15	+	+	+	+	+	+	+	+	+	+	-	-	1
63-23	+	+	+	+	+	+	+	+	+	-	+	-	1
63-31	+	+	+	+	+	+	+	+	+	+	+	-	21
63-39	+	+	+	+	+	+	+	+	+	-	-	+	2
63-63	+	+	+	+	+	+	+	+	+	+	+	+	15

[a](1)Don Timóteo; (2) G 11796; (3) Bolón Bayo; (4) Montcalm; (5) Amendoin; (6) G 5686: (7) Pan 72; (8) G 2858; (9) Flor de Mayo; (10) Mexico 54; (11) BAT 332; (12) Cornell 49-242.

[b] Compatible reaction (+)

[c]Incompatible reaction (-)

Sartorato BIC Vol 43, 2000, p 180-181

Characterization Phaeoisariopsis griseola isolates from Minas Gerais, Brazil

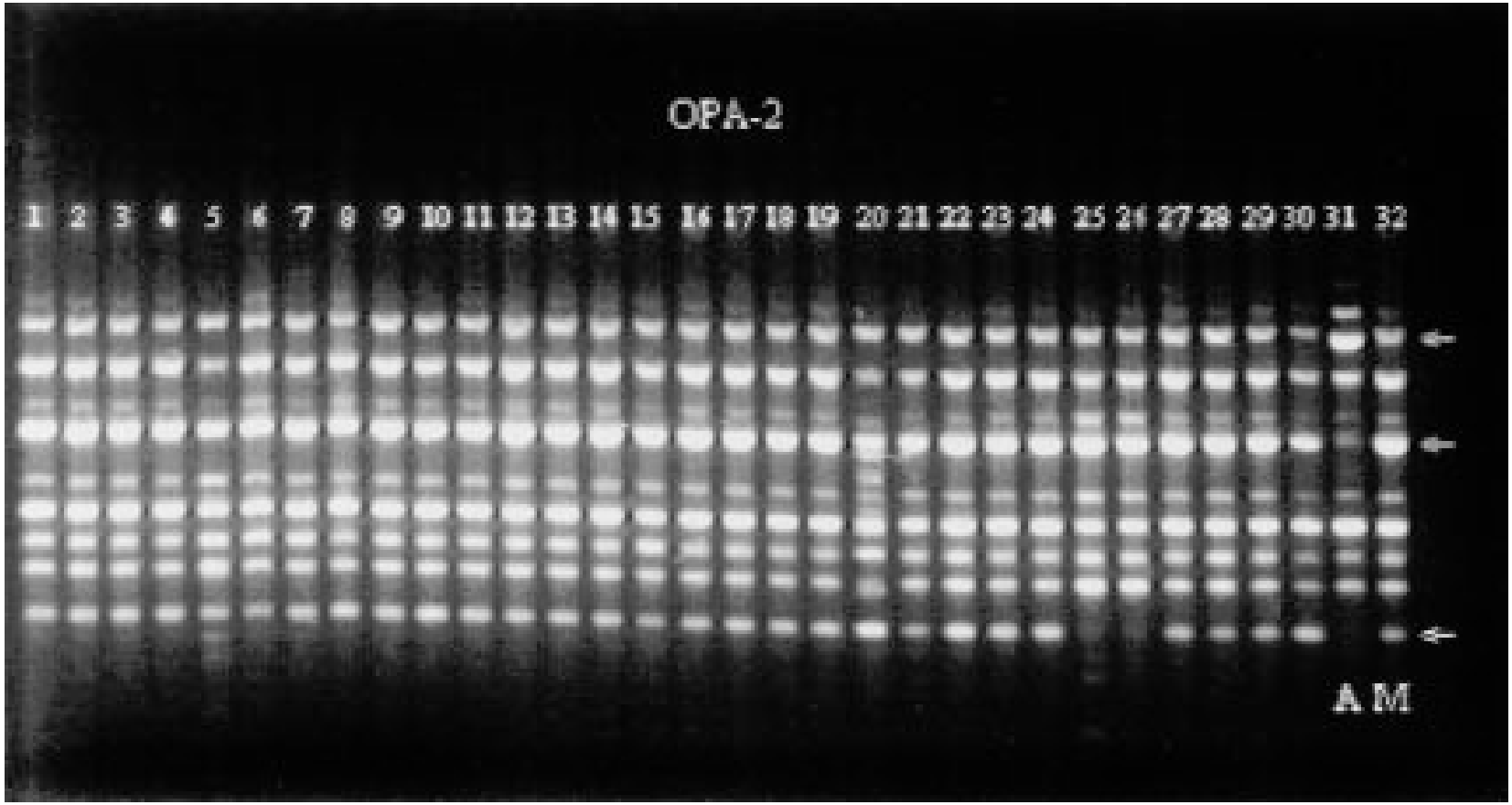
All Races are Mesoamerican

Identification number	Isolates	Phenotype virulence[1]												Races	Origin
		A	B	C	D	E	F	G	H	I	J	K	L		
1	103-1	a[2]	b	c	d	e	f	g	h	i		k		63.23	Coimbra
2	26-1	a	b	c	d	e	f	g	h	i			l	63.39	Lavras
3	4-3	a	b	c	d	e	f	g	h	i	j	k	l	63.63	Lavras
4	13-1	a	b	c	d	e	f	g	h	i	j	k	l	63.63	Lavras
5	20-2	a	b	c	d	e		g	h	i				31.7	Lavras
6	84-1	a	b	c	d	e		g	h	i		k		31.23	Coimbra
7	72-1	a	b	c	d	e		g	h	i		k		31.23	Coimbra
8	58-1	a	b	c	d	e	f	g	h	i		k	l	63.55	Coimbra
9	93-1	a	b	c	d	e		g		i		k		31.21	Coimbra
10	59-2	a	b	c	d	e	f	g	h	i				59.7	Coimbra
11	65-1	a	b	c	d	e	f	g	h	i		k		63.23	Coimbra
12	41-1	a	b	c	d	e	f	g	h	i			l	63.39	Lavras
13	17-3	a	b	c	d	e	f	g	h	i		k		63.23	Lambari
14	35-1	a	b	c	d	e	f	g	h	i		k		63.23	Patos de Minas
15	5-2	a	b	c	d	e	f	g	h	i		k		63.23	Coimbra

[1] A = Don Timóteo, B = G 11796, C = Bolón Bayo, D = Montcalm, E = Amendoim, F = G 5686, G = PAN 72, H = G 2858, I = Flor de Mayo, J = México 54, K = BAT 332 and L = Cornell 49-242.

[2] Small letters indicate virulent reaction in the differential line. **Nietsche et al. Euphytica, BIC 2001**

All 30 isolates of *Phaeoisariopsis griseola* were Mesoamerican when characterized with five RAPD primers



Eletrophoretic analysis of the products of DNA amplification of 32 *P. griseola* isolates with primer OPA-02. Lanes 1 to 30: Product of DNA amplification of 30 P. griseola isolates, lane 31 (A): Andean pattern; lane 32 (M): Mesoamerican pattern.

Nietsche et al. *Euphytica*, Vol.117, No. 1, 2001

Frequent races of *Pseudocercospora griseola* in the states of Brazil with the highest dry bean production

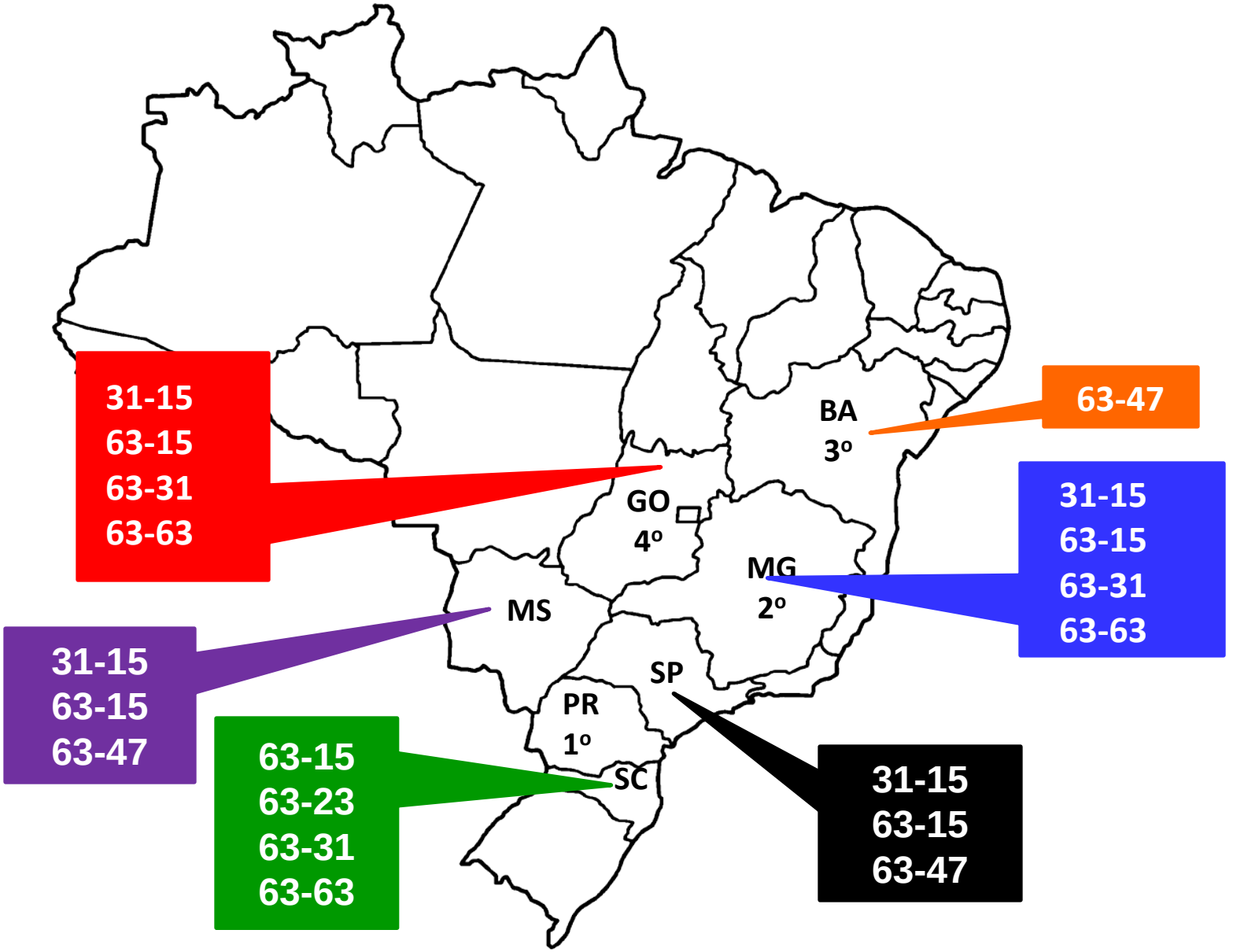


Table 4. Response of a set of bean differential cultivars to inoculation with 45*Pseudocercospora griseola* isolates collected from Uganda

Andean group[a]						Mesoamerican group[b]						Pathotype[c]	Number of isolates
a	b	c	d	e	f	g	h	I	j	k	l		
1	2	4	8	16	32	1	2	4	8	16	32		
+	-	+	-	-	-	-	+	+	-	-	-	5:6	2
+	-	+	-	-	-	-	+	+	+	+	-	5:30	4
+	-	+	-	-	-	+	+	+	+	+	-	5:31	2
+	-	+	-	-	-	+	+	+	-	+	+	5:55	2
+	-	+	-	-	-	+	-	+	+	-	-	13:13	2
+	-	+	+	-	-	+	+	+	-	+	+	13:55	2
+	-	-	-	+	-	+	+	+	-	+	-	17:23	11
+	-	-	-	+	-	+	+	+	-	-	+	17:39	5
+	-	+	-	+	-	+	+	+	-	-	+	21:38	4
+	-	+	-	+	-	+	+	+	-	-	+	21:39	8
+	-	-	+	-	+	-	+	+	-	-	-	41:6	2
+	-	+	+	+	+	+	+	+	+	+	+	61:63	1

[ab]Andean groups included cultivars: (a) Don Timoteo; (b) G 11796; (c) Bloom Bayo; (d) Montcalm; (e) Amendoin; (f) G 5686. Middle American group included cultivars: (g) Pan 72; (h) G 2858; (i) Flor de Mayo; (j) Mexico 54; (k) BAT 332; (l) Cornell 49–242.

Dbamurila et al. J. of Agricultural Science, Vol 6, 2014

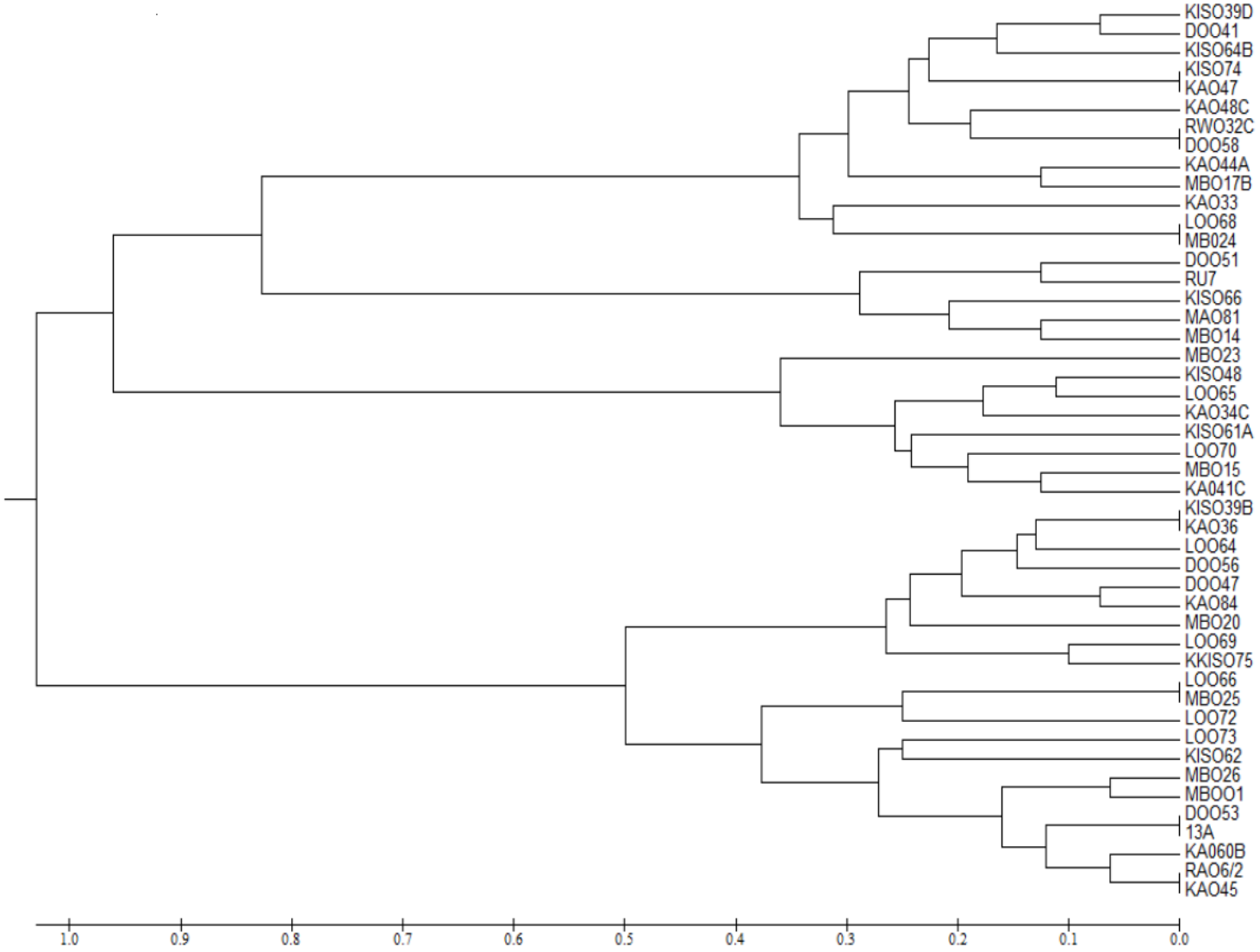


Figure 3. Dendogram generated based on RAMS and REP bands from 45 *Pseudocercospora griseola isolates from* Uganda and 2 control isolates (RU7 and 13A) from CIAT, a representative group 1(Middle America) and representative group 2 (Andean) **Dbamurila et al.. J. of Agic Sci Vol 6: 16-29, 2014**

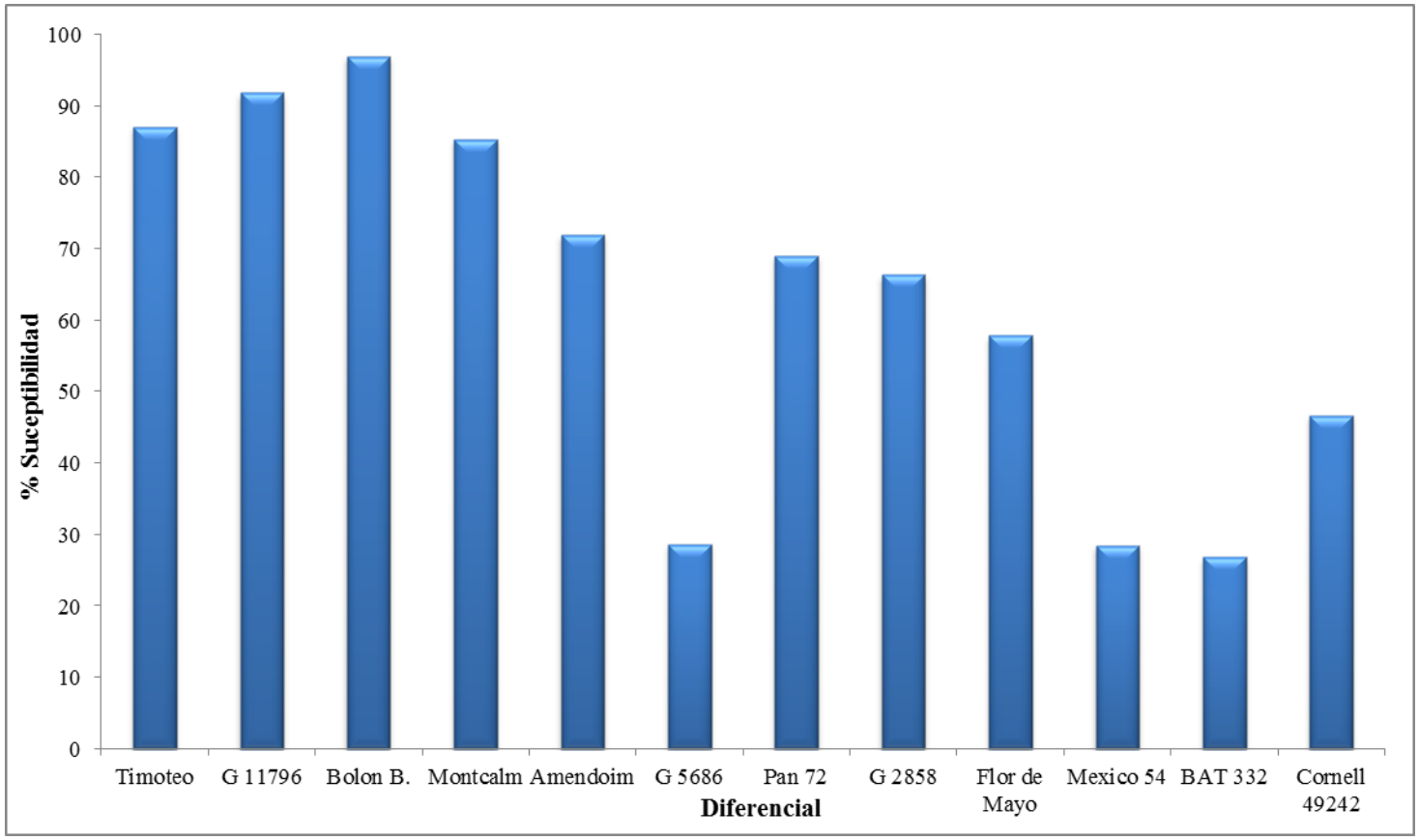
Current Status of 20-year old PG differential cultivar Set

- Race 63-63 overcomes the resistance of all differential cultivars
- Race 63-63 is a recurrent race in Brazil and other countries of Latin America
- Not reported in Africa
- Many Andean and some Mesoamerican differential are susceptible to most races in many countries

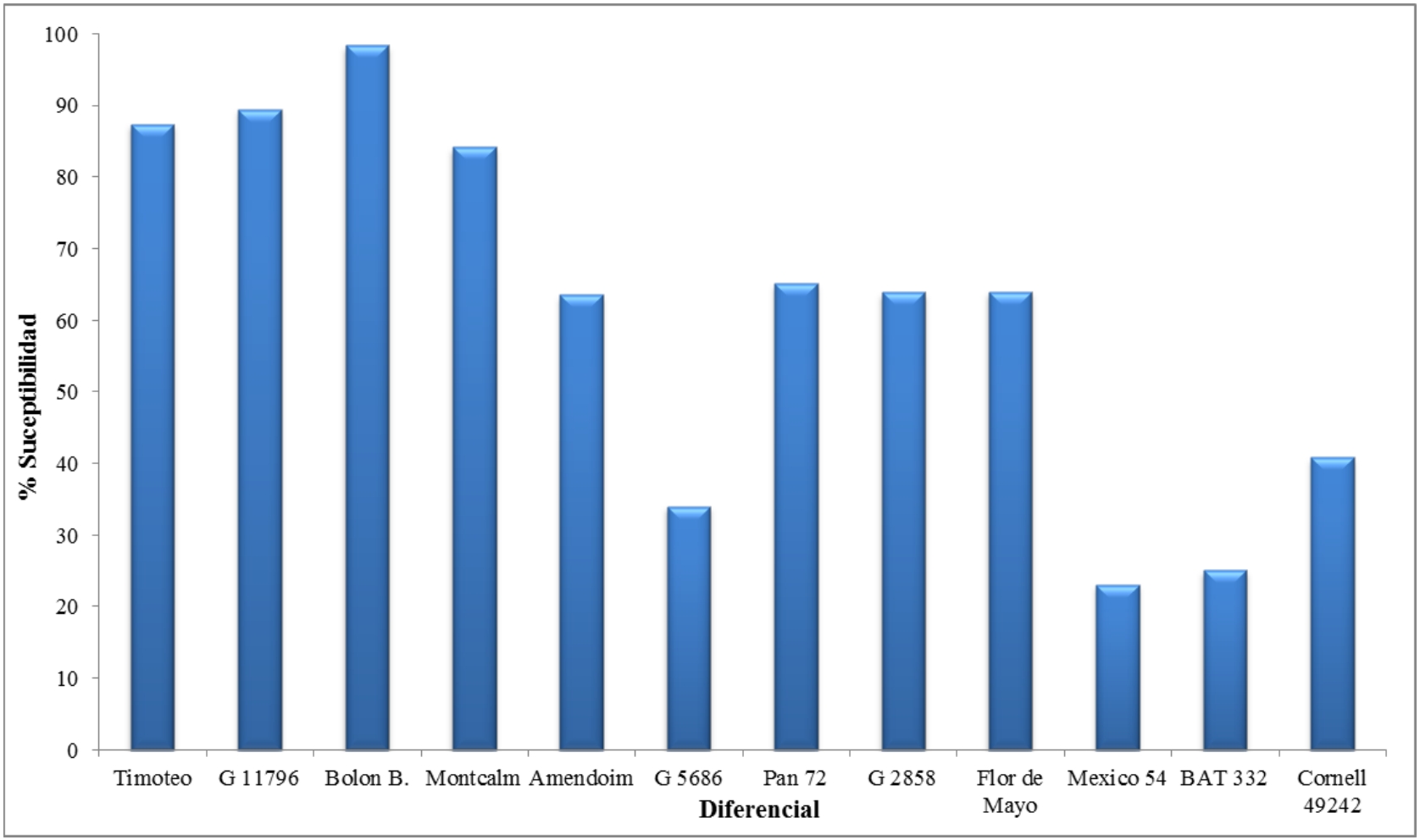
Reaction of each differential cultivar to all races of PG

- Needed to determine which differential cultivars should be changed

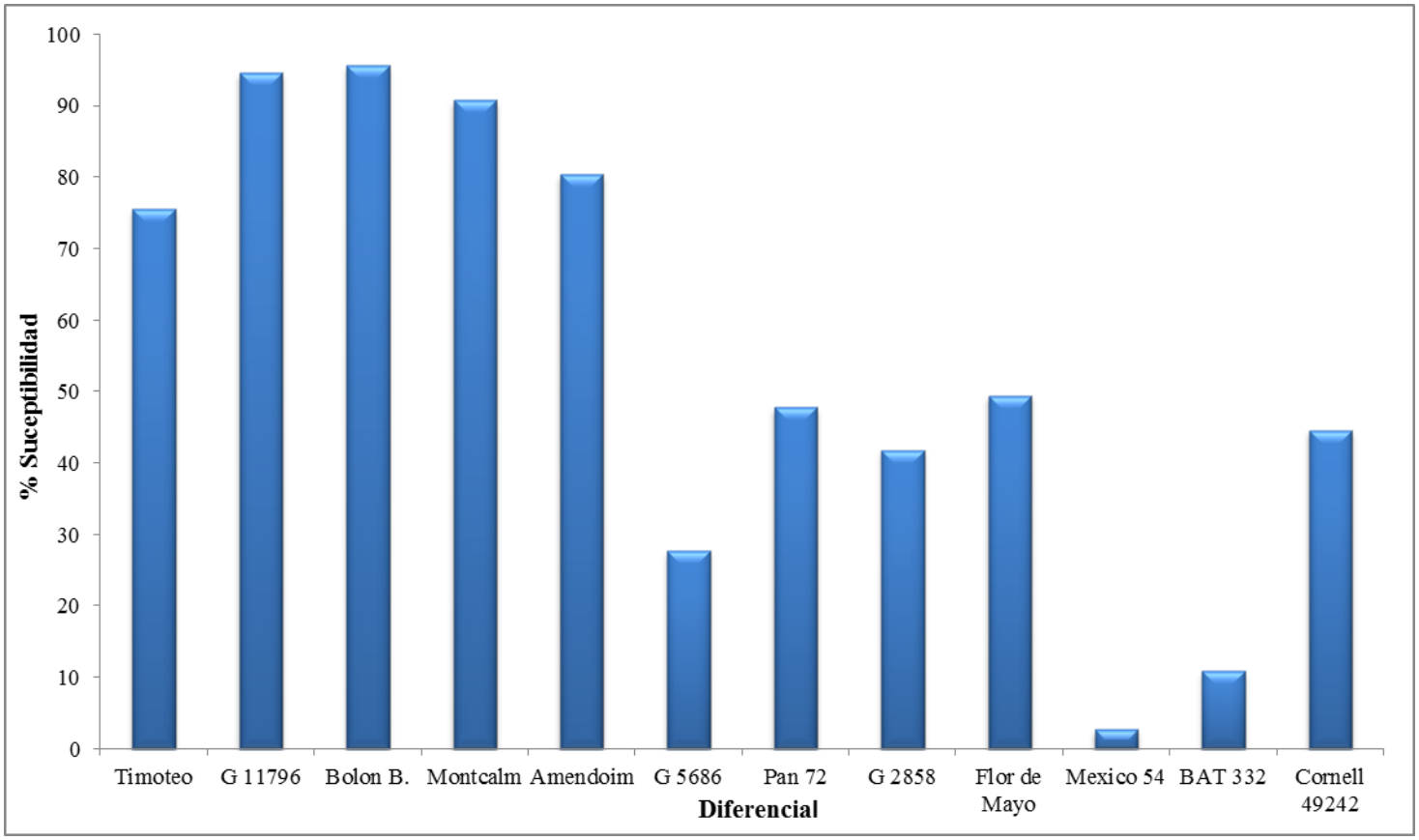
Susceptible reacción of 12 diferencial cultivarse inoculated with 589 isolates de *Pseudocercospora griseola* from America and Africa



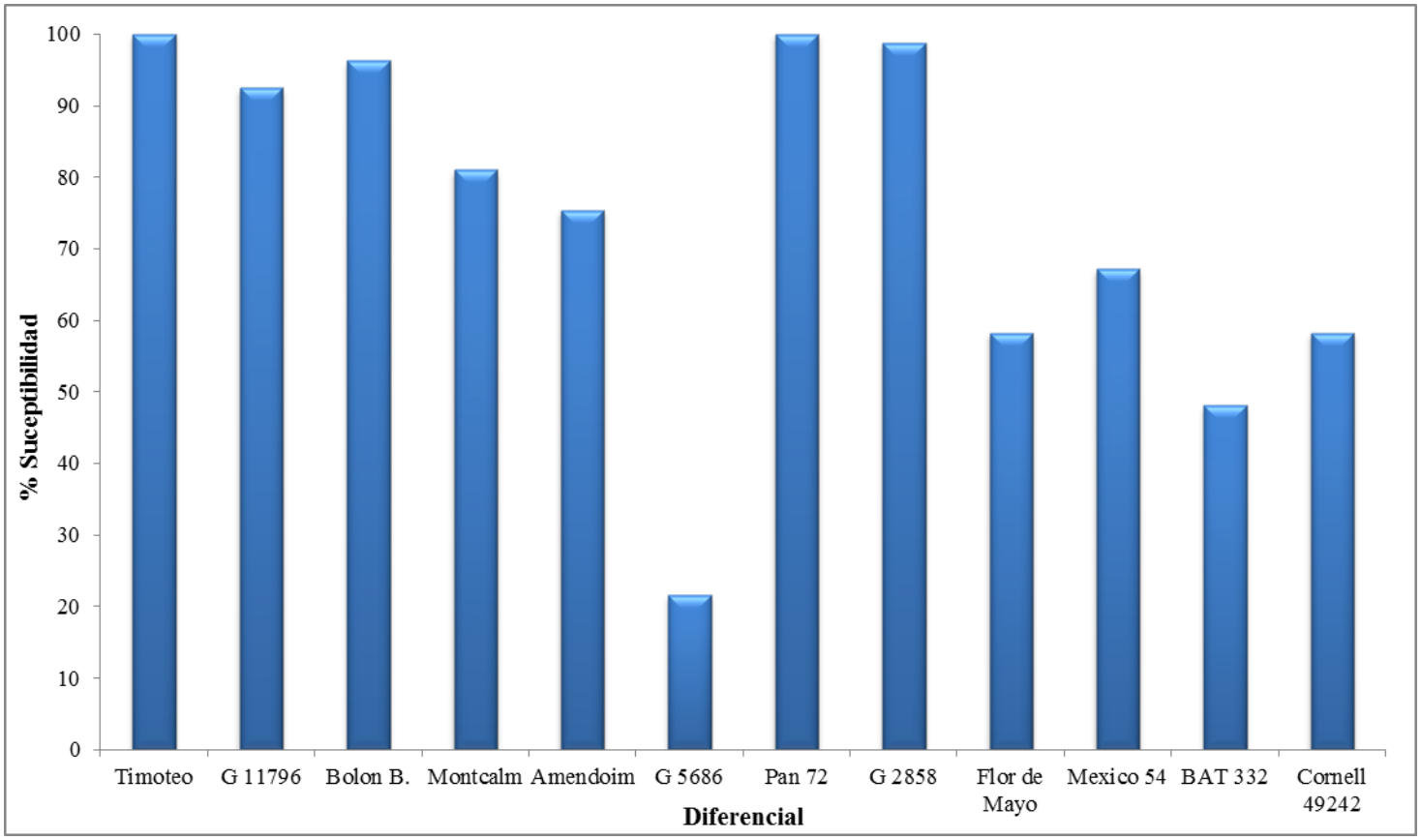
Susceptible reacción of 12 diferencial cultivarse inoculated with 247 isolates de *Pseudocercospora griseola* from South América



Susceptible reacción of 12 diferencial cultivarse inoculated with 184 isolates de *Pseudocercospora griseola* from África



Susceptible reacción of 12 diferencial cultivarse inoculated with 158 isolates de *Pseudocercospora griseola* from Central America

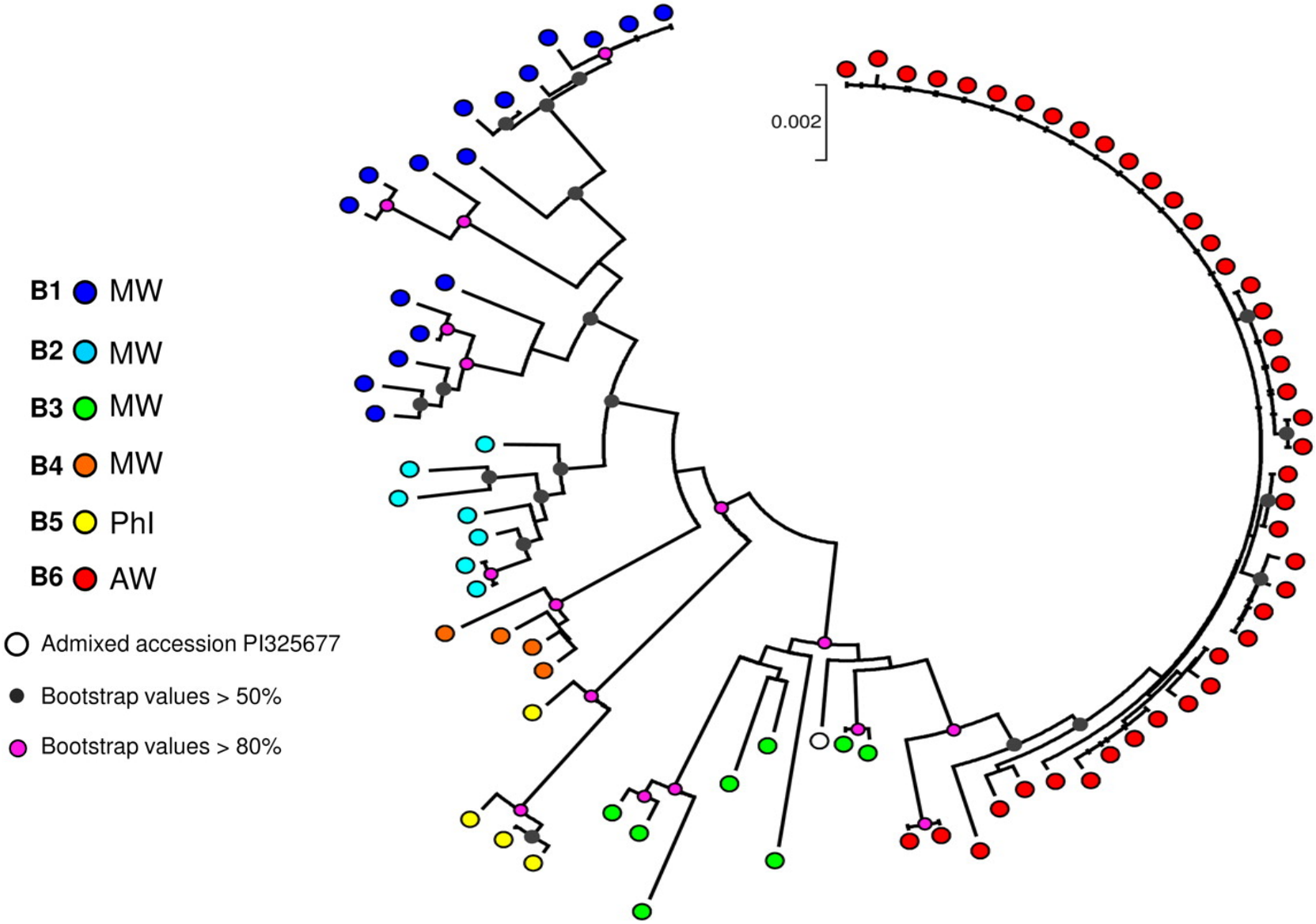


Correspondence between diversity of PG and its common bean host

- PG is highly variable: virulence and genetic
- Violence diversity of PG analogous to diversity of it host:
- Mesoamerican PG races and Mesoamerican wild and domesticated beans have greater diversity

Correspondence between diversity of PG and its common bean host

- Andean resistance genes are not inferior R genes
- Mesoamerican resistance genes are not superior R genes
- These are complementary genes needed for the development of bean genotypes with durable ALS resistance

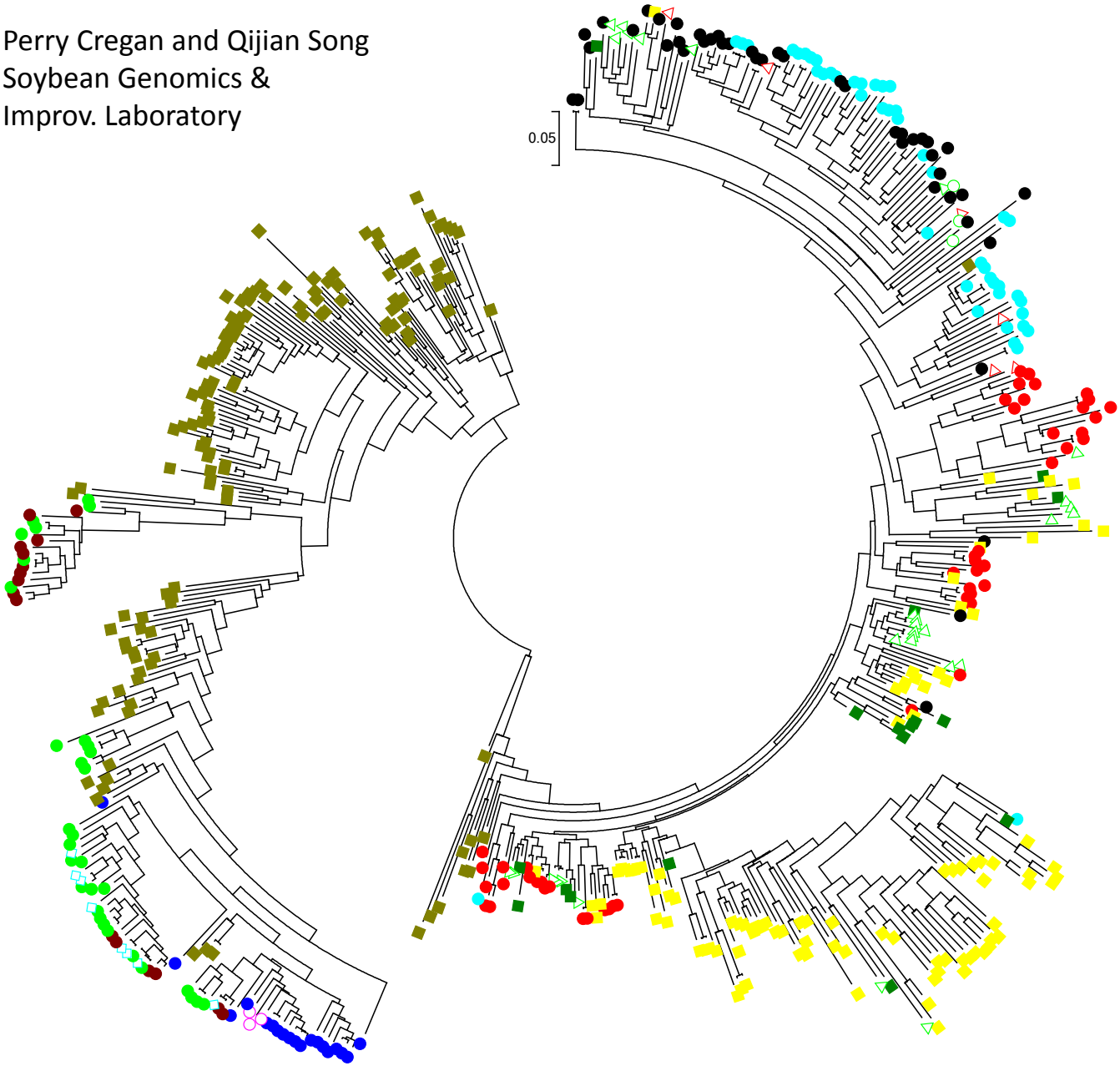


Unrooted NJ bootstrap tree inferred from the concatenate sequence data. Each set of accessions (as indicated) is represented by a colored circle, and each color indicates the membership to the BAPS groups. Small gray and violet circles represent the nodes for which bootstrap values are higher that 50% and 80%, respectively (the 80% threshold highlights the relationships with very strong support). AW, Andean wild; MW, Mesoamerican wild; PhI, type I phaseolin (northern Peru–Ecuador).

Bitocchi et al. PNAS, Vol. 109, No. 14, 2011.

Neighbor Joining Tree - 502 BeanCAP Snap and Dry bean Genotypes Analyzed with 10,154 SNPs

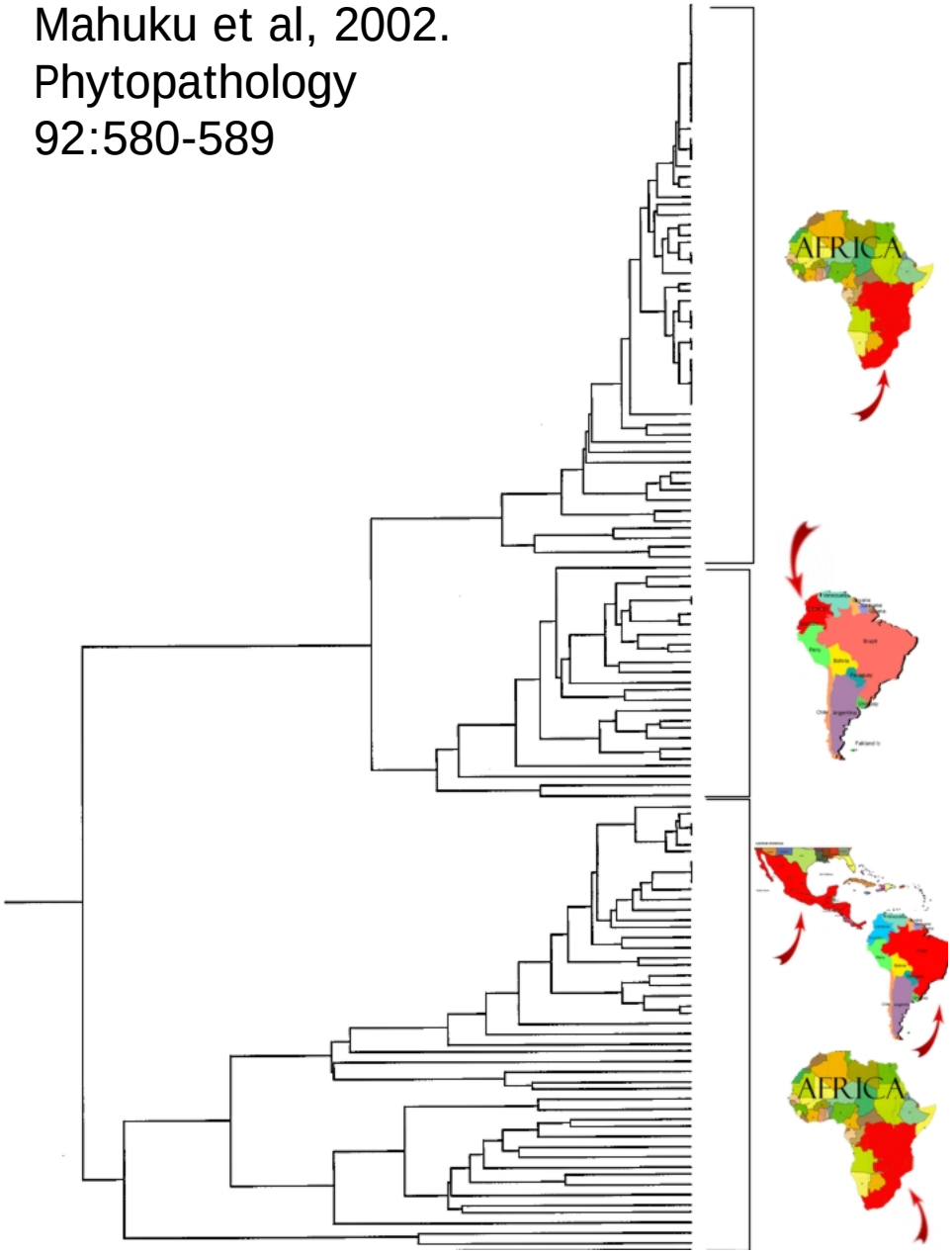
Perry Cregan and Qijian Song
Soybean Genomics &
Improv. Laboratory



Snap Bean (134)
LRK (32)
Cranberry (19)
DRK (15)
WK (8)
Red Mottle (3)

Pinto (91)
Gt. Northern(48)
Black (42)
Navy (43)
Small Red (29)
Pink (17)
Small White (6)
Tan (3)

Mahuku et al, 2002.
Phytopathology
92:580-589



131 Andean and Mesoamerican PG isolates revealed by RAPD and RAMS DNA markers

Andean isolates
from Africa

Andean isolates
from South America

Mesoamerican isolates
from Latin America and Africa

Reaction of 24 Dry Bean Cultivars to Isolates of *Phaeoisariopsis griseola*

Correa, F.J. and Saettler, A.W. ALS of RK beans in MI. Plant Dis. 71:915-918,1987

		ALS Disease reaction induced by Isolate		
Class	**Cultivar**	**Michigan 4**	**Michigan 5**	**Wisconsin**
Navy	C 20	R	R	R
	Laker	R	R	R
	NEP II	R	R	R
Black	Black Beauty	R	R	R
	Black Magic	R	R	R
	Black T. Soup	R	R	R
Pinto	Olathe	R	R	R
	UI-111	R	R	R
Red Kidney	Charlevoix	S	S	S
	Isabella	S	S	S
	Montcalm	S	S	S
Cranberry	MI Imp 28	S	S	S
	Taylor Hort	S	S	S

Bean differential cultivars most resistant to *Phaeoisariopsis griseola* in Latin America and Africa

Differential cultivar			Resistant to races (%)[a]		
Identification	Seed Size	Bean Race	Andean	Mesoamerican	African
G 5686[d]	Large	Nueva Granada	80	96	81
BAT 332	Small	Mesoamerica	100	48	73
Cornell 49242	Small	Mesoamerica	100	33	64
MEX 54	Medium	Jalisco	100	37	100

a. Total number of races: five Andean (includes all races from Ecuador and Colombia isolated from large-seeded cultivars), and all 27 Mesoamerican includes races from Colombia, Brazil, Bolivia, Central America, and Mexico isolated from small- or medium-seeded cultivars), for a total of 32 different races occurring in Latin America.

b. Susceptible only to race 63 (Andean) and 1023 (Mesoamerican), both from Latin America, and to races 511 and 1407 from Africa.. G 5686 is resistant to all other races occurring in Latin America and Africa.

1994 CIAT Annual Report - Bean Program

Reaction of four bean differential cultivars for four races of *Phaeoisariopsis griseola* from Latin America and Africa that attack G 5686.

	Number of Isolates		Cultivar Reaction			
Race	Latin America	Africa	G 5686	BAT 332	Cornell 49242	MEX 54
63	4	0	Susceptible	Resistant	Resistant	Resistant
1023	2	0	Susceptible	Resistant	Resistant	Susceptible
511	0	2	Susceptible	Resistant	Resistant	Resistant
1407	0	1	Susceptible	Susceptible	Resistant	Resistant

Bean Improvement Cooperative, Annual Report (USA), 1994.

Before agriculture only wild beans existed

For a long time

There was not decisive proof that wild beans were related to domesticated common beans

Parallel gene pools were discovered in Wild and domesticated genes

- Wild and domesticated beans have two major gene pools
  - Mesoamerican and Andean
- These gene differ in:
  - Morphology
  - Agronomic traits
  - Seed proteins
  - Allozymes
  - Different types of molecular markers

Differences Between Domesticated Andean and Mesoamerican common beans

Characteristic	Gene Pool	
	Andes	Mesoamerica
Seed Size	Large	Small, Medium
Phaseolin seed Protein	T, C, H, A	S, Sb, Sd, B
Allozyme	Diap-I^{100}, Lap-3^{103}, $Rbcs^{98}$, $Skdh^{103}$	Dap-I^{95}, Lap-3^{100}, $Rbcs^{100}$, $Skadh^{100}$

Seeds of Wild and Domesticated Mesoamerican and Andean common Beans

Implications of the diversity and evolution studies of common bean to bean pathology

- Beans from the Mesoamerican wild and domesticated gene pool were much more diverse gene pool compared with the Andean
- Much broader virulence diversity observed on ANT, ALS, and rust isolates from Mesoamerican bean than from Andean beans

Summary of Diversity Studies Results of ANT, ALS, Rust Pathogens

- Two groups of populations
- Essentially two gene pools
- Mirrors diversity of host

Andean races:

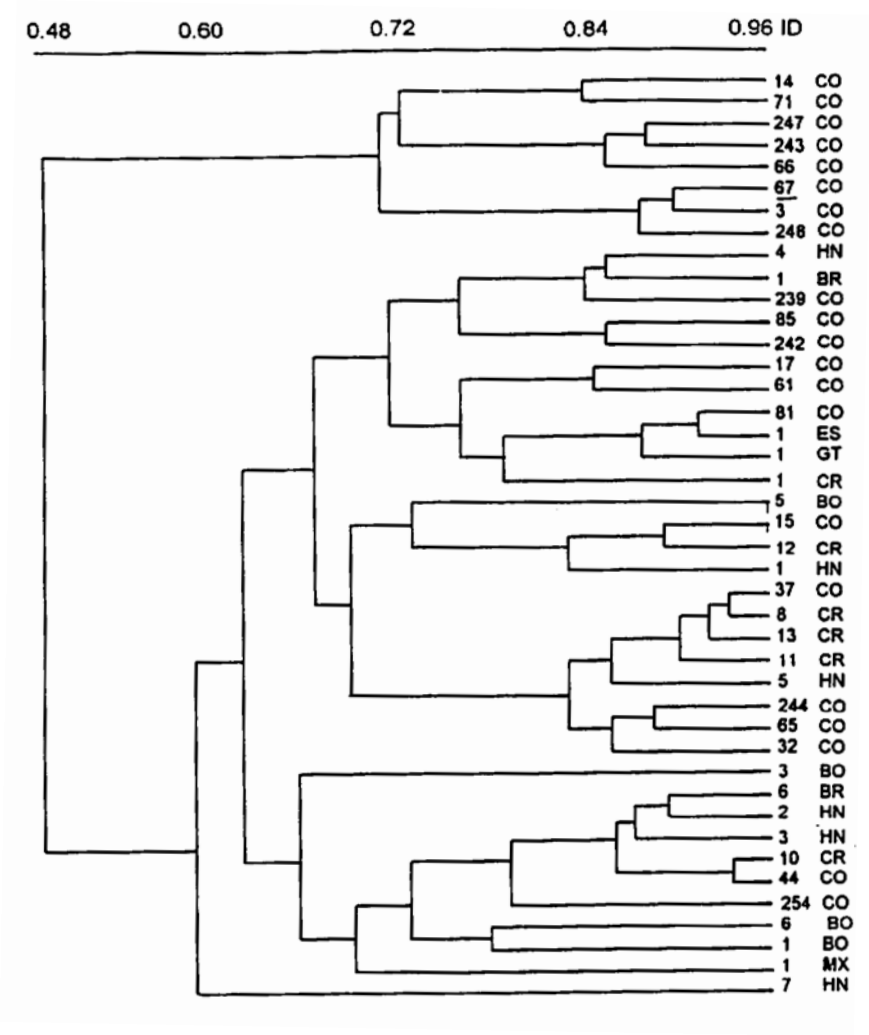
- Narrow and specific host range
- Infect only or mostly Andean beans
- Less virulence diverse

Distribution and variability of PG in Uganda

- Ddamurila et al, J. of Ag Sci Vol 6: 16-29, 2014
- Studied incidence, severity and diversity of PG in 10 districts of Uganda
- 45 PG isolates studied
- Virulence diversity:
  - Using 12 differential cultivars
- Genetic diversity:
  - Using RAMS and Conserved sequences

Distribution and variability of PG in Uganda

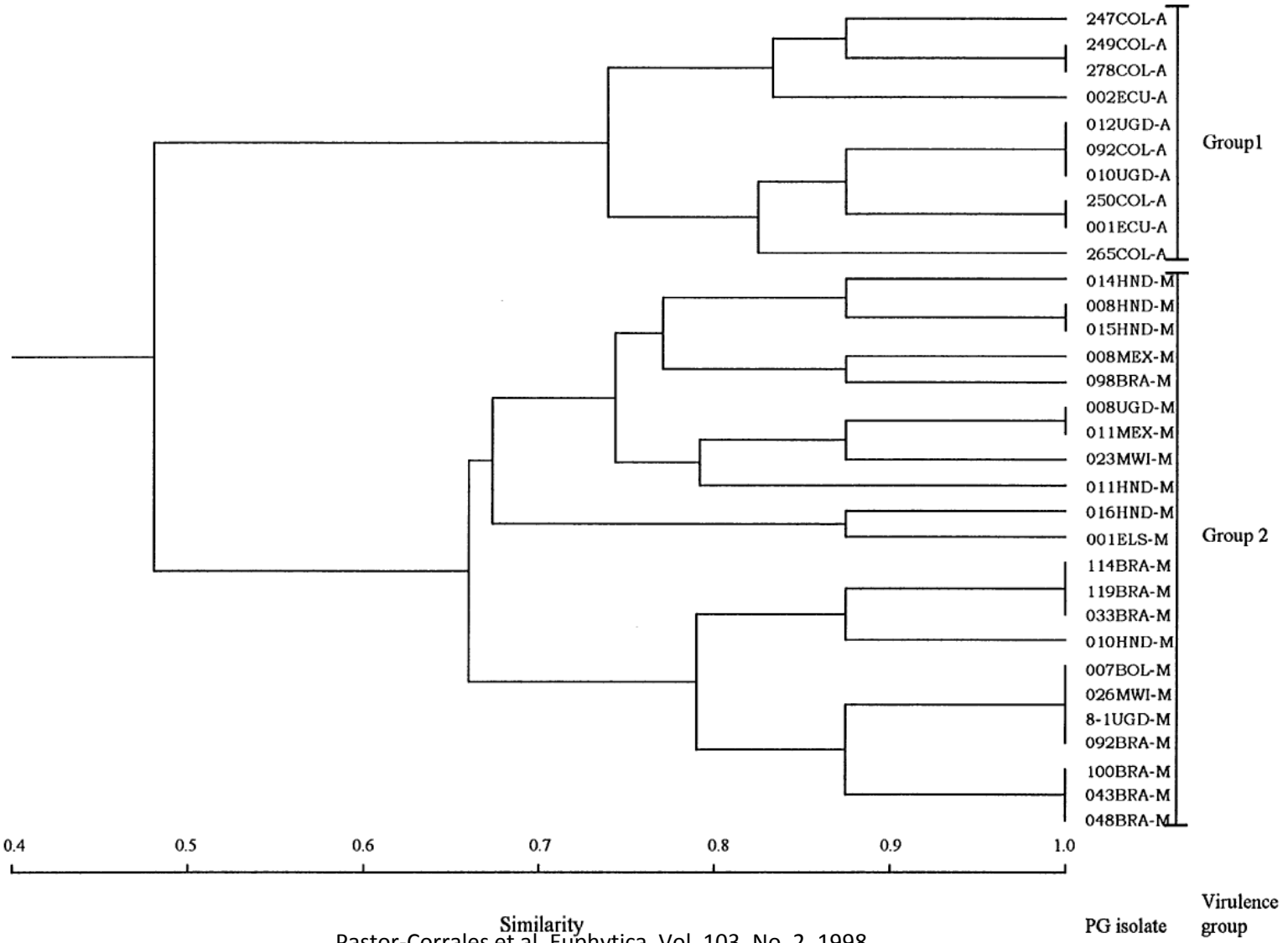
- 12 races characterized
- All races infected Andean and Mesoamerican differential cultivars
- Most isolates appear to be Mesoamerican
- Results from genetic diversity analysis unrelated to virulence diversity



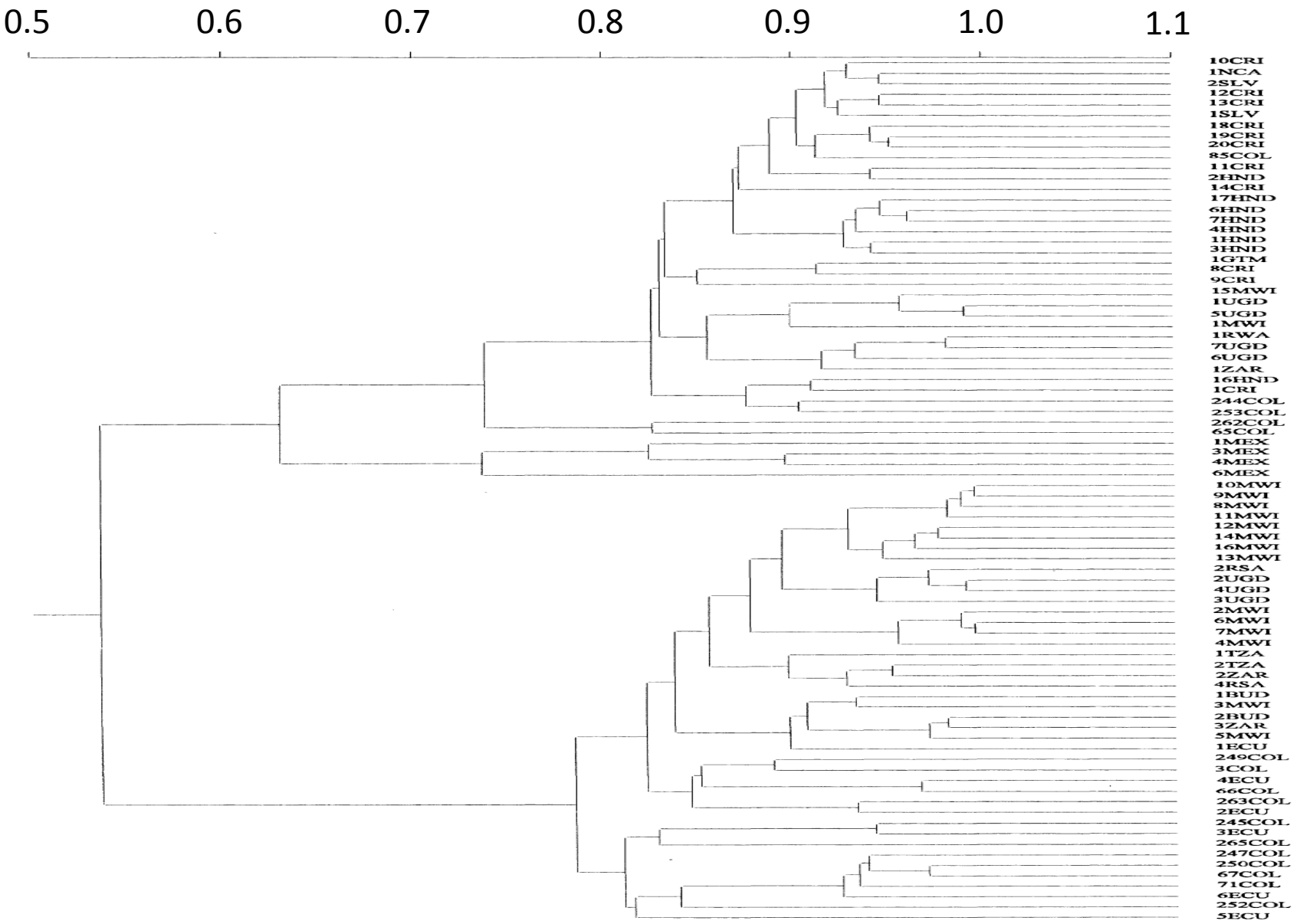
Dendogram of 42 isolates of *Phaeoisariopsis griseola* from Latin America based on virulence phenotypes obtained from the inoculation of a set of 12 differential cultivars, showing the separation of isolates into two large groups.

Pastor-Corrales and Jara, *Fitopatologia Colombiana*, Vol. 19, No. 1, 1995.

Dendrogram of virulence phenotype, using eight of 12 landrace differential cultivars and 32 of *Phaeoisariopsis griseola (PG) isolates* collected from known landraces of Andean (A) and Middle American (M) common bean used for screening in the greenhouse. Groups 1 and 2 are Andean and Middle American PG isolates, respectively. To identify PG isolates, the three digits indicate the serial number of the isolate, the three letter codes indicate the country of origin (see footnote of Table 2), and the letter A or M indicates the large-seeded Andean or the small or medium-seeded Middle American common bean landrace, respectively, from which it was collected.

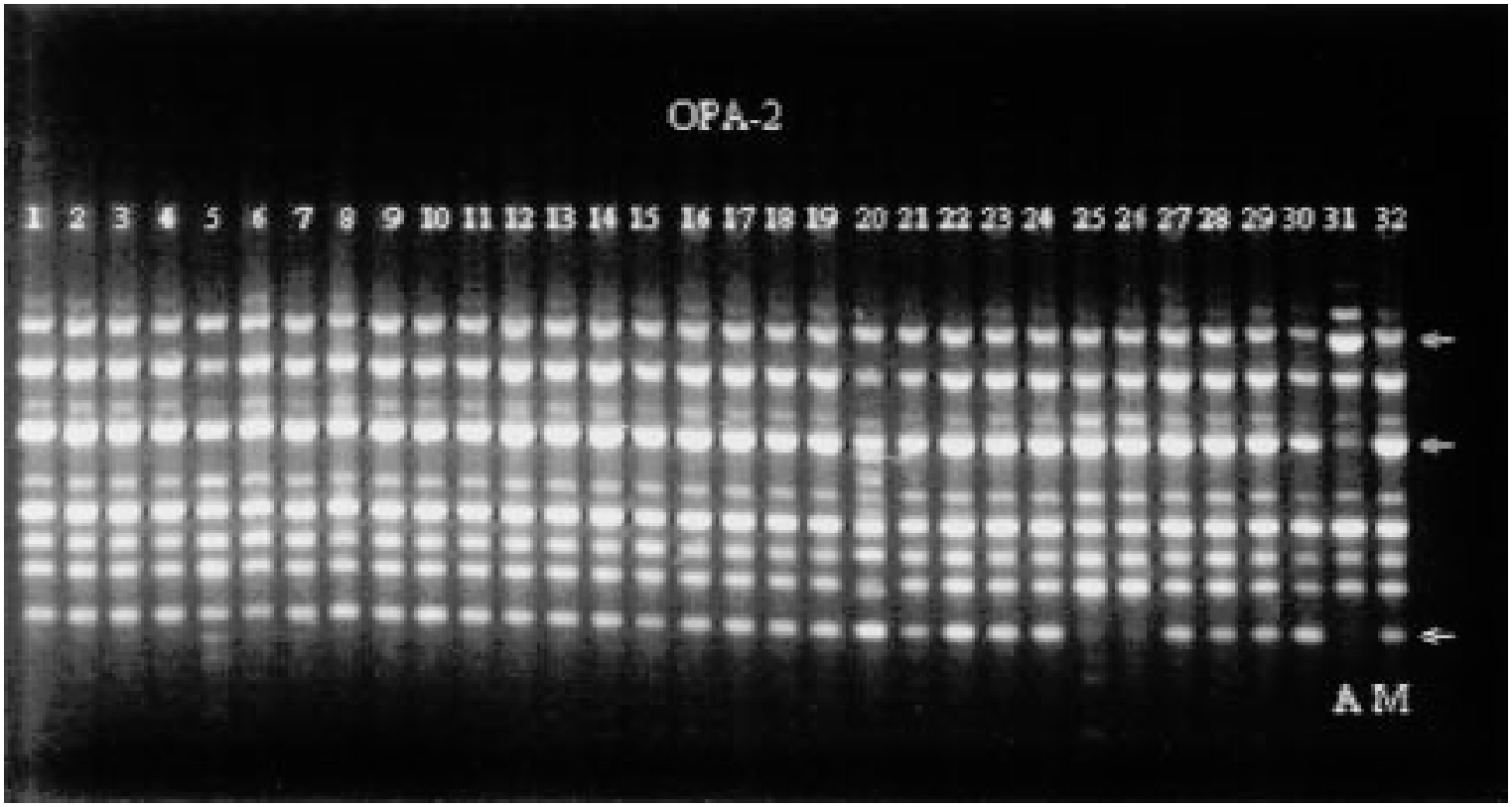


Pastor-Corrales et al. Euphytica, Vol. 103, No. 2, 1998.



RAPD Data dendrogram of *P. griseola* isolates from South America and Africa.

Chacón et al. Bean Improvement Cooperative. Annual Report (USA), 40, 1997.



Eletrophoretic analysis of the products of DNA amplification of 32 *P. griseola* isolates with primer OPA-02. Lanes 1 to 30: Product of DNA amplification of 30 P. griseola isolates, lane 31 (A): Andean pattern; lane 32 (M): Mesoamerican pattern.

Nietsche et al. *Euphytica*, Vol.117, No. 1, 2001

All in All
This was a Seminal Study

- 55 PG isolates from 14 countries in the Americas and Africa
- Their virulence diversity characterized using a new set of Andean and Mesoamerican differential cultivars
- **Revealed Andean and Mesoamerican races of the ALS pathogen**

Some Races of *Phaeoisariopsis griseola* are widely distributed in Brazil

See race 63-63

Table 2. Geographical distribution of pathotype and isolates of *Phaeoisariopsis griseola* identified in Brazil.

Pathotype	Isolate Origin					Total Num of Isolates
	SC[a]	PR	GO	MG	PB	
31-23				1		1
55-31				1		1
63-15	1					1
62-23	1					1
63-31	12	2	4	3		21
63-39				1	1	2
63-63	9		2	4		15
Total	23	2	6	10	1	42

[a](SC) Santa Catarina; (PR) Paraná; (GO) Goiás; (MG) Minas Gerais; (PB) Paraiba

Sartorato BIC Vol 43, 2000, p 180-181

Main Losses Caused by ALS

- **Reduces**
  - **Pod and seed quality**
  - **Seed number and size**
  - **Produces infected seed**

Survival of ALS Pathogen on Seed

- Infested and Infected seed
- Moves pathogen from one location or planting season to another

Pseudocercospora griseola

Coniodiophore

Rising Conidium

Conidium

Crouss, et al, 2006. Re-evaluating the taxonomic status of *Phaeoisariopsis griseola*, the causal agent of angular leaf spot of bean. Studies in Mycology 55: 163-173

Characterization Phaeoisariopsis griseola isolates from Minas Gerais, Brazil

All racess are Mesoamerican

Identification number	Isolates	Phenotype virulence[1]												Races	Origin
		A	B	C	D	E	F	G	H	I	J	K	L		
16	68-2	a	b	c	d	e		g		i		k		31.21	Coimbra
17	29-3	a	b		d	e	f	g	h	i		k	l	63.55	Lambari
18	36-3	a	b	c	d			g	h	i			l	15.39	Patos de Minas
19	97-2	a	b	c	d	e		g	h	i	j	k		31.15	Coimbra
20	85-1	a	b	c	d	e	f	g	h	i		k		63.23	Coimbra
21	104-1	a	b	c	d	e	f	g	h	i		k		63.23	Coimbra
22	99-1	a	b	c	d	e	f	g	h	i		k		63.23	Coimbra
23	94-1	a	b	c	d	e	f	g	h	i		k		63.23	Coimbra
24	109-1	a	b	c	d	e	f	g	h	i		k		63.23	Coimbra
25	28-2	a	b	c	d	e	f	g	h	i			l	63.39	Lambari
26	46-2	a	b	c	d		f	g	h	i		k		47.39	Paracatu
27	60-1	a	b	c	d	e	f	g	h	i		k	l	63.55	Lavras
28	87-2	a	b	c	d	e		g	h	i		k	l	31.55	Coimbra
29	53-1	a	b	c	d	e	f	g	h	i	j	k		63.31	Lavras
30	55-1	a	b	c	d	e		g	h	i		k		31.23	Lavras

[1] A = Don Timóteo, B = G 11796, C = Bolón Bayo, D = Montcalm, E = Amendoim, F = G 5686, G = PAN 72, H = G 2858, I = Flor de Mayo, J = México 54, K = BAT 332 and L = Cornell 49-242.

[2] Small letters indicate virulent reaction in the differential line.

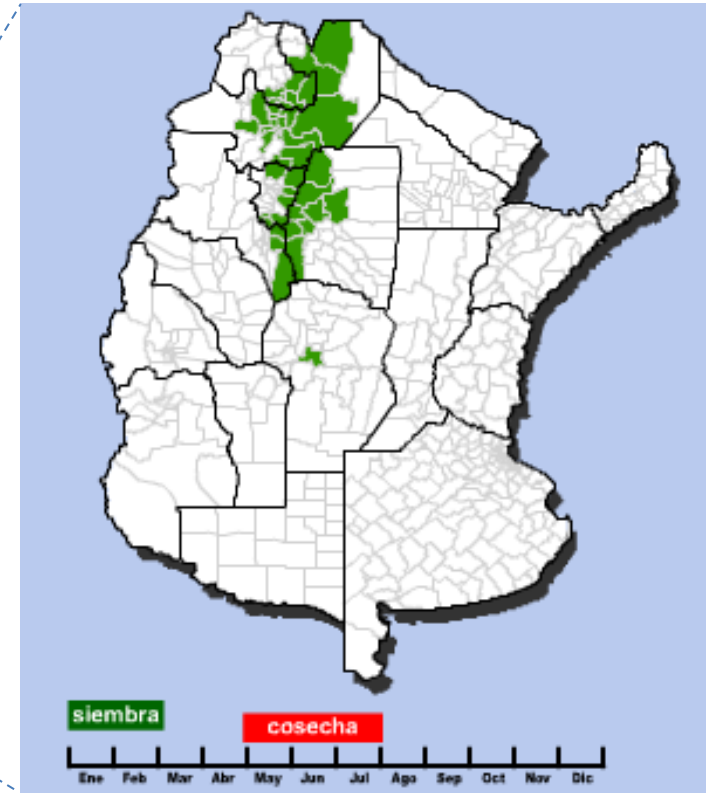
Nietsche et al. *Euphytica*, BIC 2001

Bean production in Argentina

- Argentina exports 98% of the production and it is among the major exporting countries of common bean worldwide

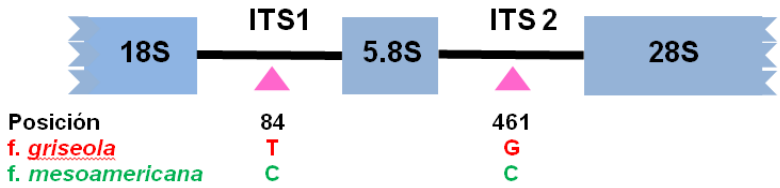
- Cultivated area: NW region (provinces of Salta, Jujuy, Tucumán, Catamarca and Santiago del Estero)

- Production: 360.000 tn/year
  (Salta 70% of the production)



Phaeosiariopsis griseola genetic diversity in Argentina

- SCARs, ITS-rDNA (poster)

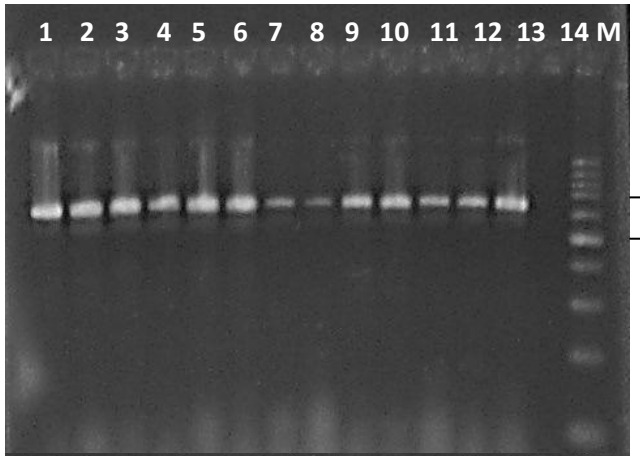


Polimorphic sites in ITS regions
(JX454536-71, KC806244-51)

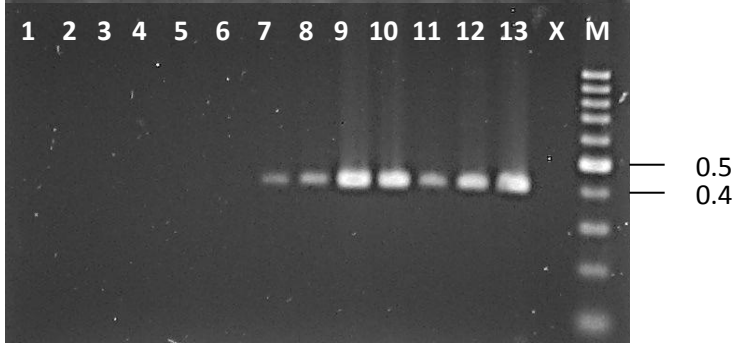
SCARs

(Guzmán et al., 1999 specific primers)

Mesoamerican group
specific primers
(did not discriminate)



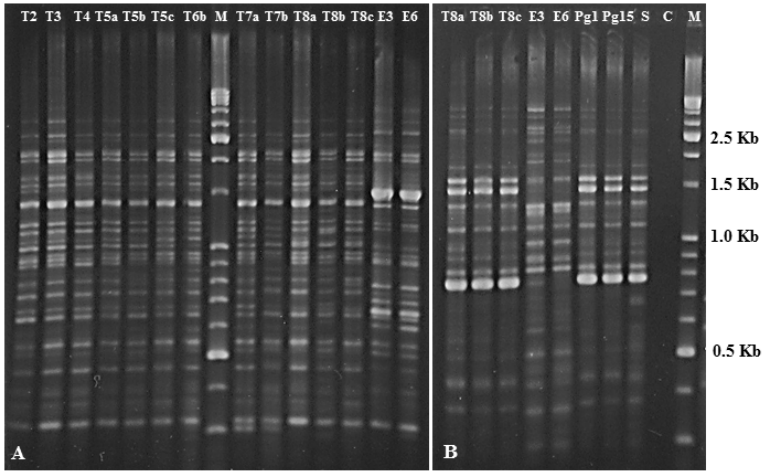
Andean group
specific primers

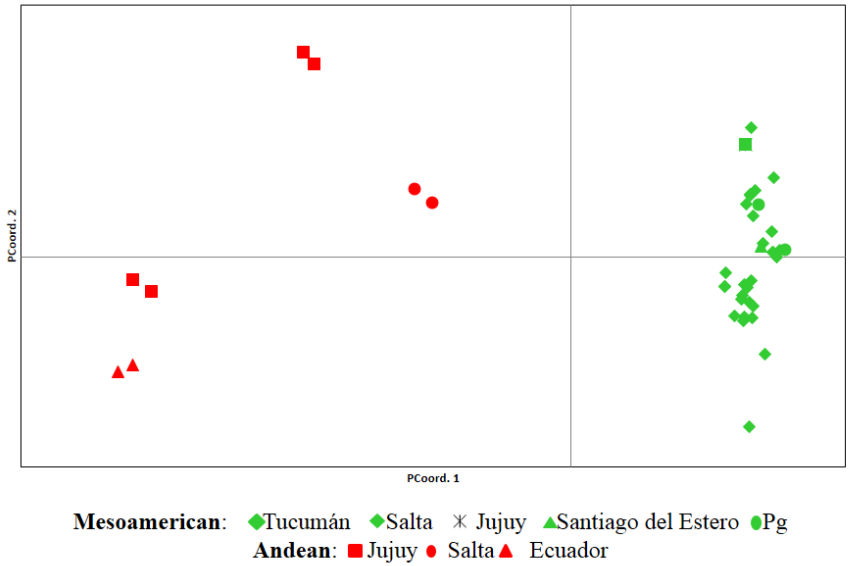


Phaeosariopsis griseola genetic diversity in Argentina

- URP (poster)

URP





URP markers were more efficient than the other markers for characterization of isolates

Most of the isolates showed unique multilocus patterns. The Andean isolates showed a higher dispersion suggesting lower genetic similarity than the Middle American isolates.