Phenotypic and genetic characterization of partial resistance to crown rust in oat (*Avena sativa L.)*

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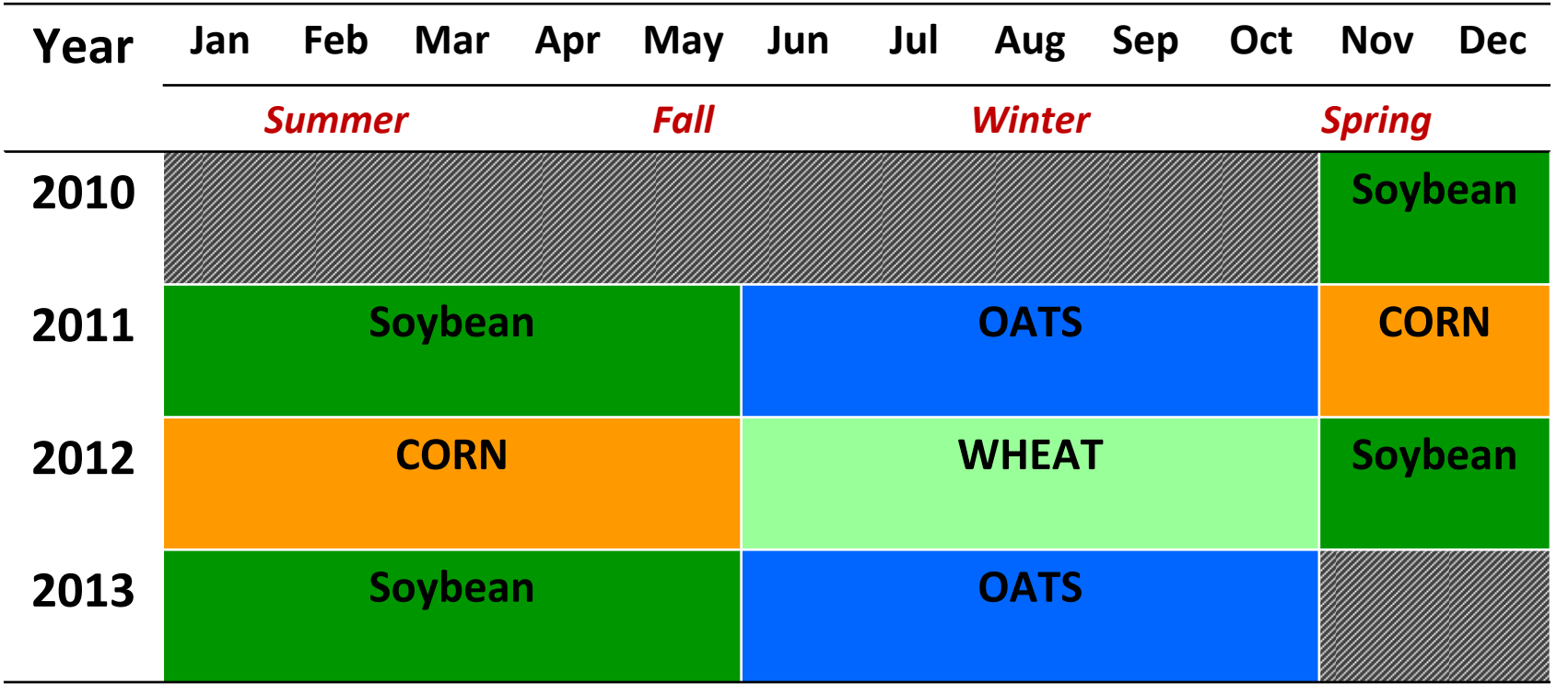
Sub tropical environment

Great variability among years

- –temperature
- –amount of rain - moisture
- –solar radiation

- **Low pH > 6.0**
- **Aluminum (Al^{+++}) in the soil**
- **Large planting date - broad adaptation**
- **Two crops a year**
- **Biotic and abiotic stresses - new varieties**

Crop rotation over three years diagram in the Southern Brazil

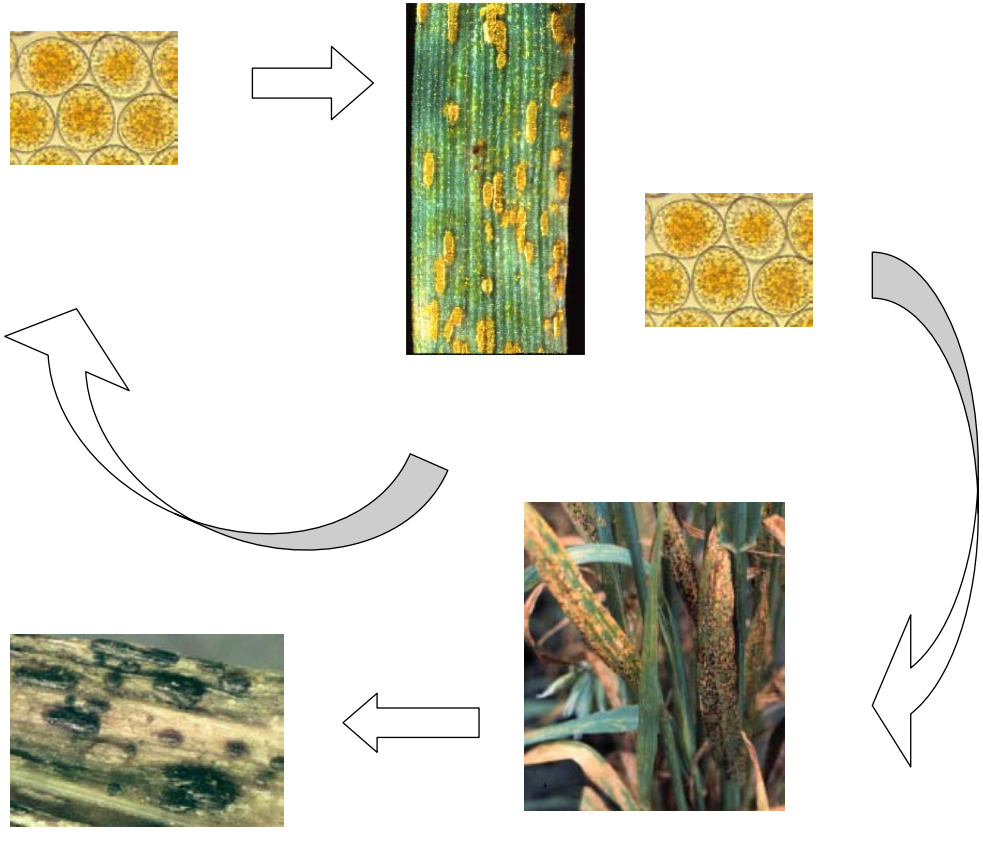


No-tillage system

Environment x crown rust:

- Humid sub tropical (cfa)
- Many hosts
  - *Avena spp., Secale cereale, Hordeum vulgare, Lolium spp., Festuca spp., Bromus inermis,* among others.
- Green bridges in the summer
- Rust found all year
- Temperature (16-23 ° C)

Crown Rust cycle



Natural crown rust epidemic in Brazil

URS 22: high susceptible variety

Guarapuava - PR
Latitude 25º S
Altitude 3,675 feet

Complexity of races in the environment (Hot spot)

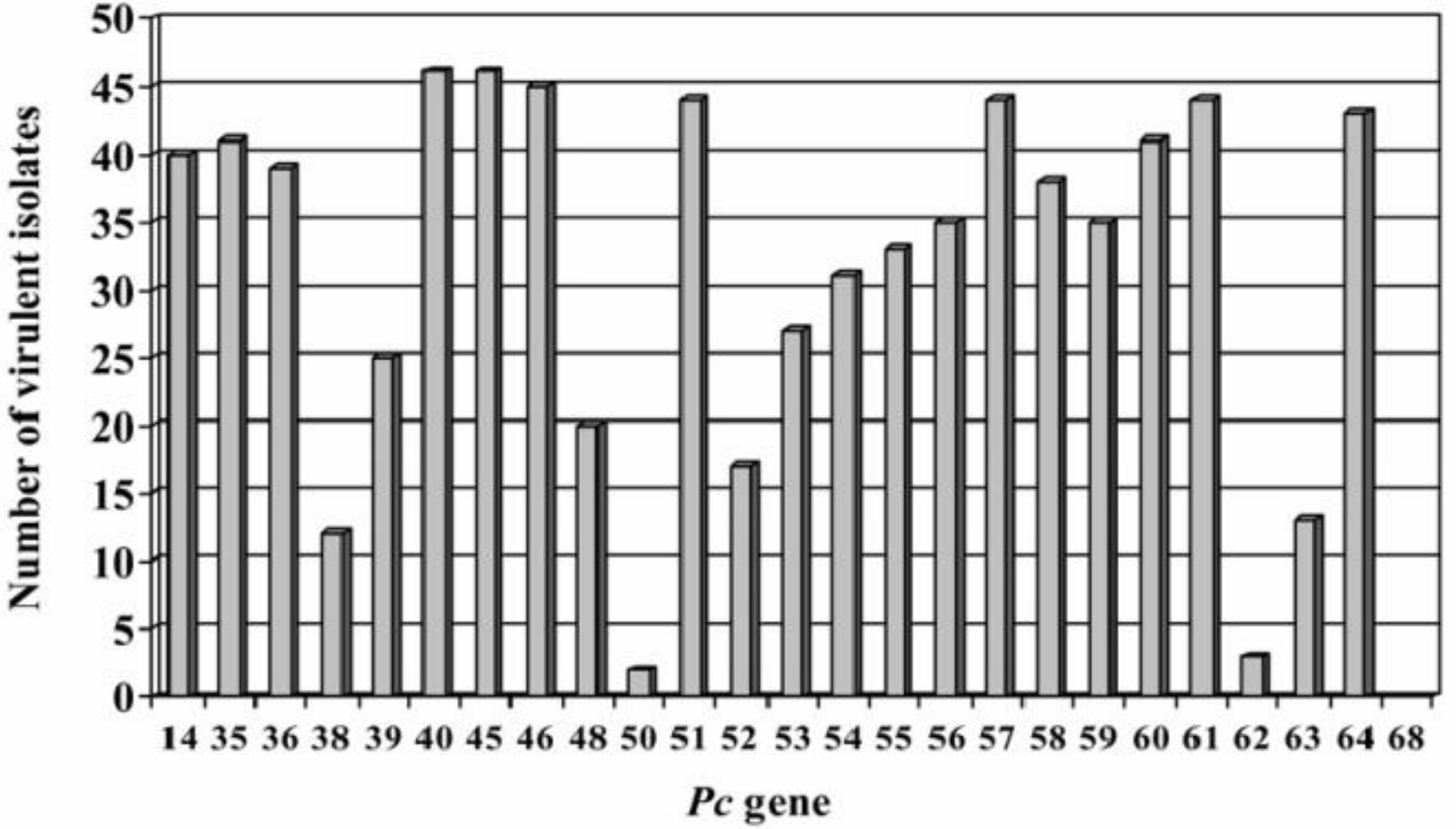
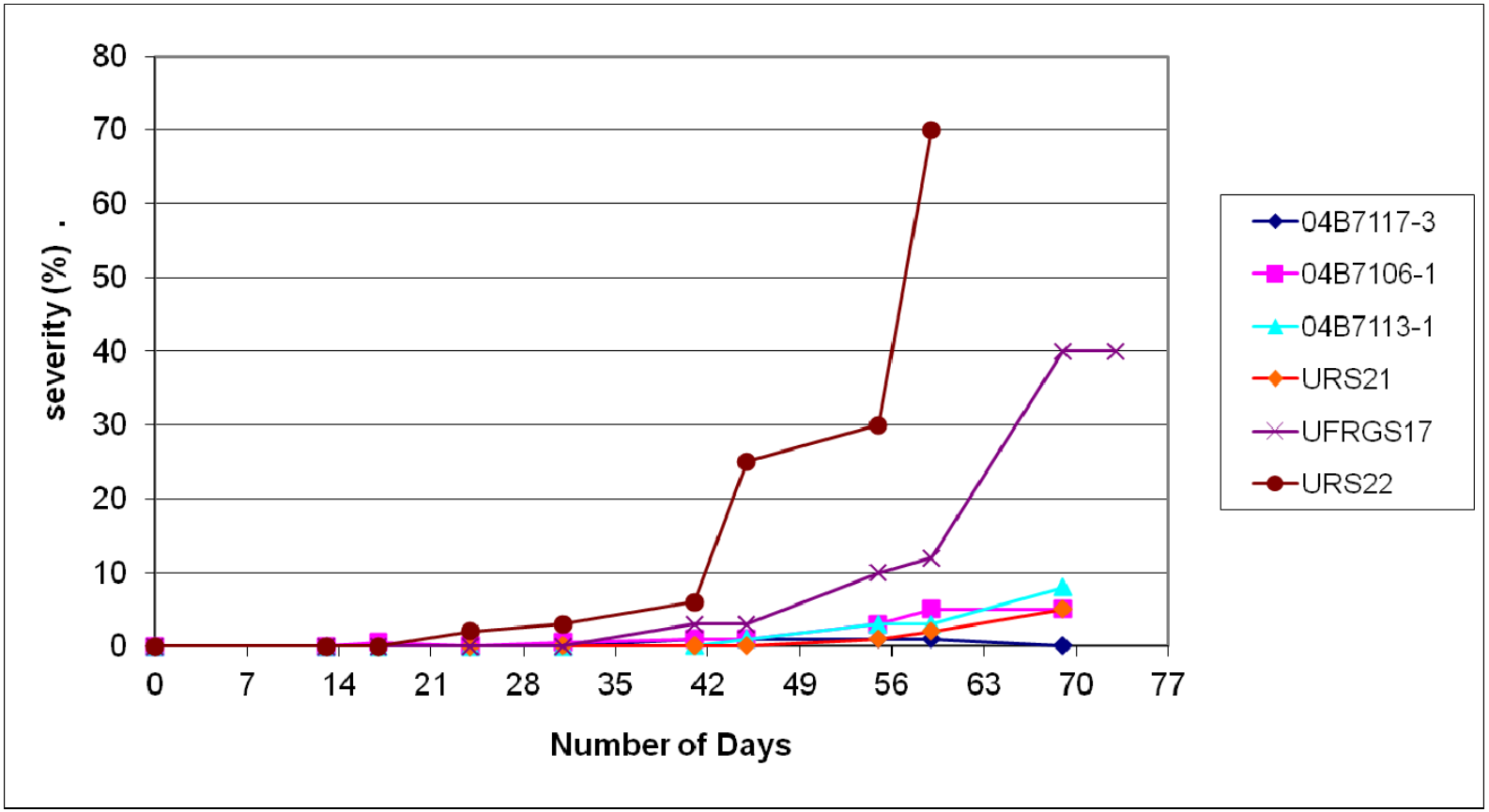


Tabela 2. Número e percentual de isolados de *Puccinia coronata* f. sp. *avenae* Fraser & Led virulentos (vir) e avirulentos (avir) aos 25 genes (*Pc*s) estudados, nas populações Capão do Leão (CL), Passo Fundo (PF) e Eldorado do Sul (EL). FAEM/UFPel, 2005

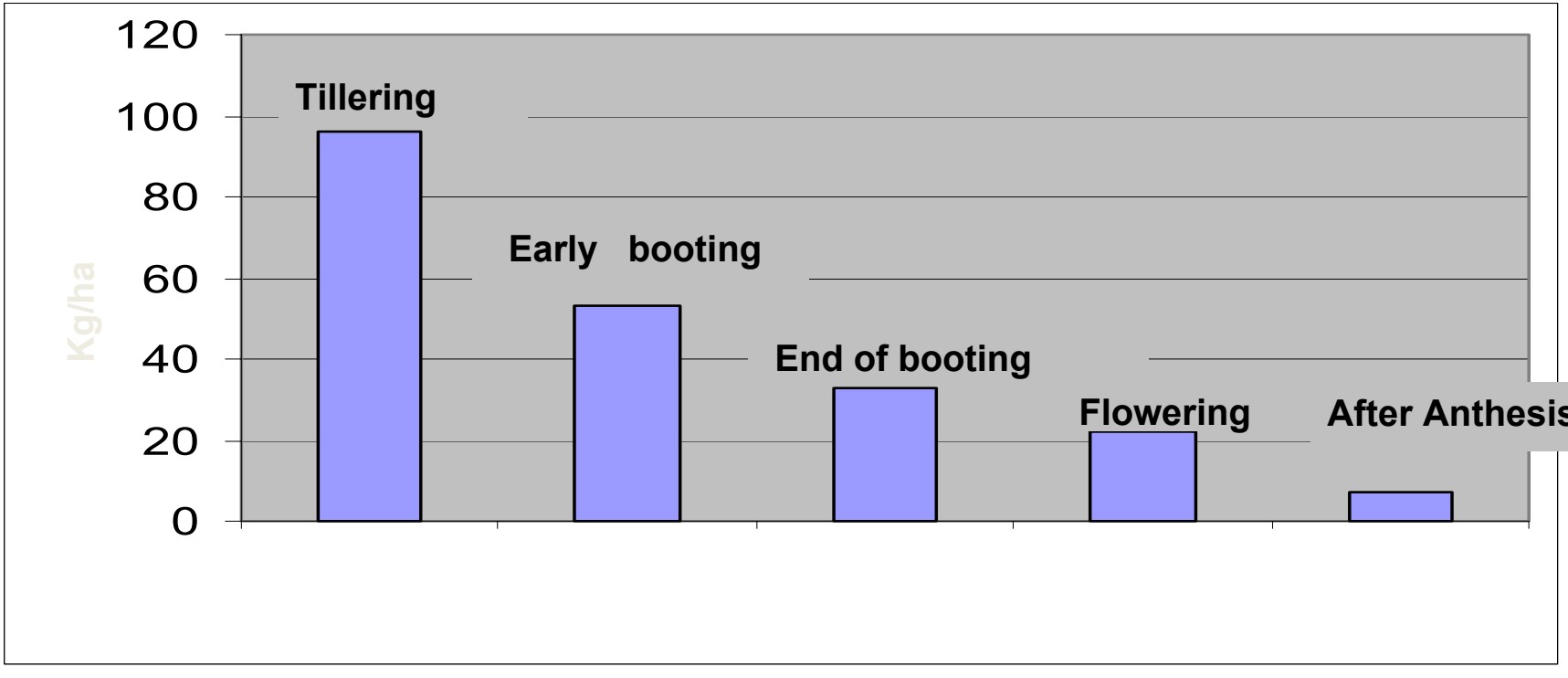
	População (EL)		População (CL)		População (PF)	
*Pc*s	Número e % de vir	Número e % de avir	Número e % de vir	Número e % de avir	Número e % de vir	Número e % de avir
40	15 (100)	0 (0)	16 (100)	0 (0)	15 (100)	0 (0)
45	15 (100)	0 (0)	16 (100)	0 (0)	15 (100)	0 (0)
46	14 (93)	1 (7)	16 (100)	0 (0)	15 (100)	0 (0)
50	0 (0)	15 (100)	2 (13)	14 (88)	0 (0)	15 (100)
38	1 (7)	14 (93)	6 (38)	10 (63)	5 (33)	10 (67)
39	8 (53)	7 (47)	11 (69)	5 (31)	6 (40)	9 (60)
48	10 (67)	5 (33)	7 (44)	9 (56)	3 (20)	12 (80)
68	0 (0)	15 (100)	0 (0)	16 (100)	0 (0)	15 (100)
51	15 (100)	0 (0)	16 (100)	0 (0)	13 (87)	2 (13)
52	11 (73)	4 (27)	6 (38)	10 (63)	0 (0)	15 (100)
58	13 (87)	2 (13)	11 (69)	5 (31)	14 (93)	1 (7)
59	14 (93)	1 (7)	9 (56)	7 (44)	12 (80)	3 (20)
54	9 (60)	6 (40)	14 (88)	2 (13)	8 (53)	7 (47)
56	14 (93)	1 (7)	12 (75)	4 (25)	9 (60)	6 (40)
62	1 (7)	14 (93)	1 (6)	15 (94)	1 (7)	14 (93)
64	15 (100)	0 (0)	14 (88)	2 (13)	14 (93)	1 (7)
14	14 (93)	1 (7)	14 (88)	2 (13)	12 (80)	3 (20)
35	14 (93)	1 (7)	13 (81)	3 (19)	14 (93)	1 (7)
36	15 (100)	0 (0)	13 (81)	3 (19)	11 (73)	4 (27)
53	11 (73)	4 (27)	5 (31)	11 (69)	11 (73)	4 (27)
55	11 (73)	4 (27)	13 (81)	3 (19)	9 (60)	6 (40)
57	15 (100)	0 (0)	15 (94)	1 (6)	14 (93)	1 (7)
60	15 (100)	0 (0)	14 (88)	2 (13)	12 (80)	3 (20)
61	15 (100)	0 (0)	16 (100)	0 (0)	13 (87)	2 (13)
63	1 (7)	14 (93)	6 (38)	10 (63)	6 (40)	9 (60)
Total	266 (70)	109 (30)	266 (67)	134 (33)	232 (62)	143 (38)


severity (%) .
80
70
60
50
40
30
20
10
0
0
7
14
21
28
35
42
49
56
63
70
77
Number of Days
04B7117-3
04B7106-1
04B7113-1
URS21
UFRGS17
URS22

Crown rust economic threshold

(20-30% Incidence or 0.5% severity at tillering)

Effect of each 1% severity on yield at different development stages.



Yield reduction is related to the stage of development.

Partial resistance

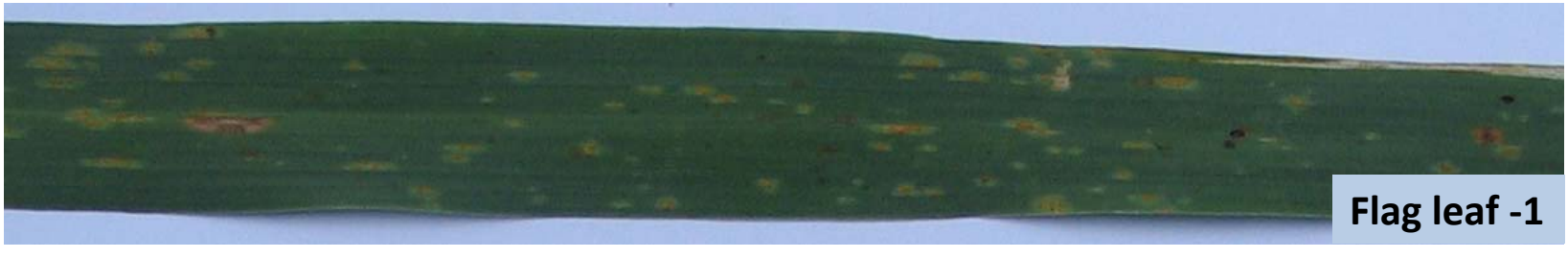
A special case of incomplete resistance, characterized as a low amount of disease accompanied by a high infection type.

(Parlevliet and van Ommeren, 1975)

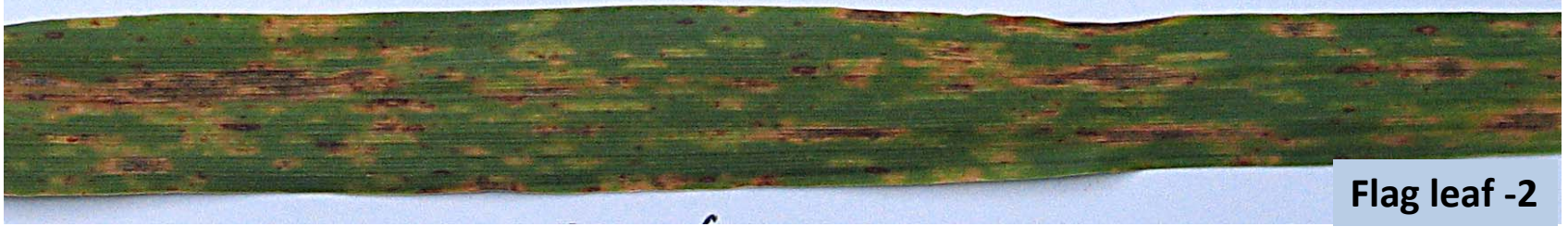
URS 21

a successful crow rust partial resistant oat variety from Brazil

- Yield trials from 1996 to 1999
- Released: 2000
- High grain
- High grain yield stability
- High milling yield
- Immune to crown rust up to 2004
- Found later it was partially resistant to crown rust

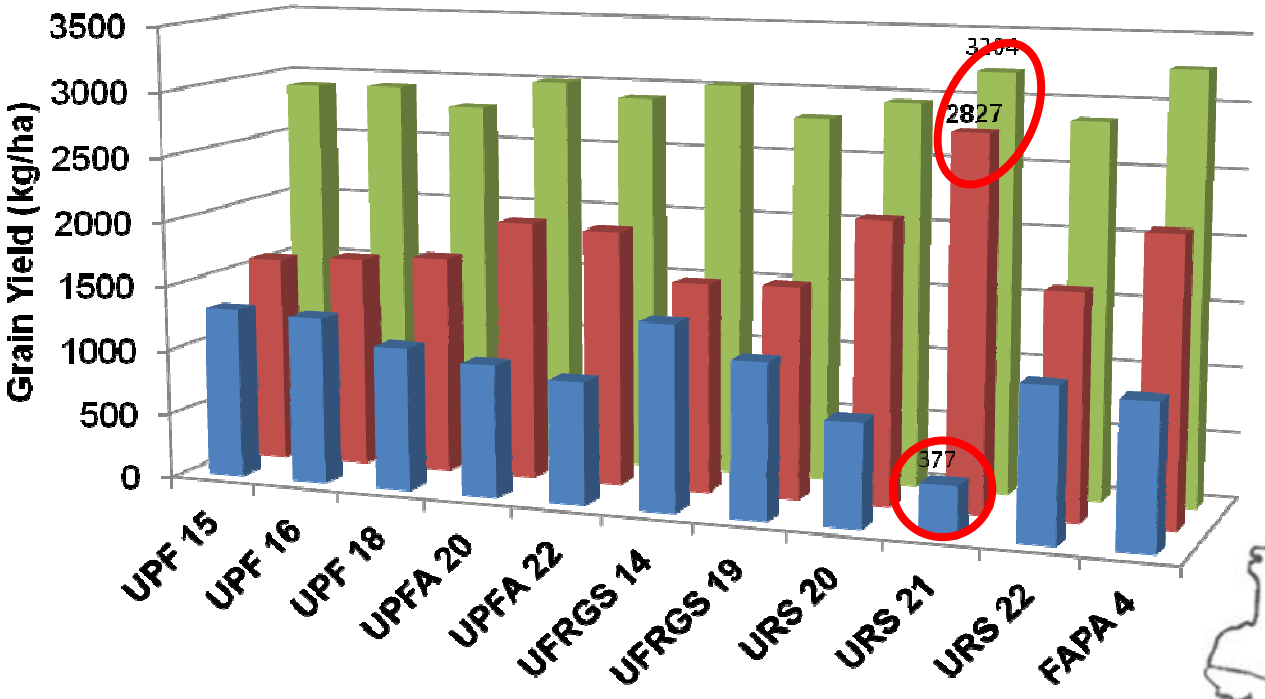


Flag leaf -1



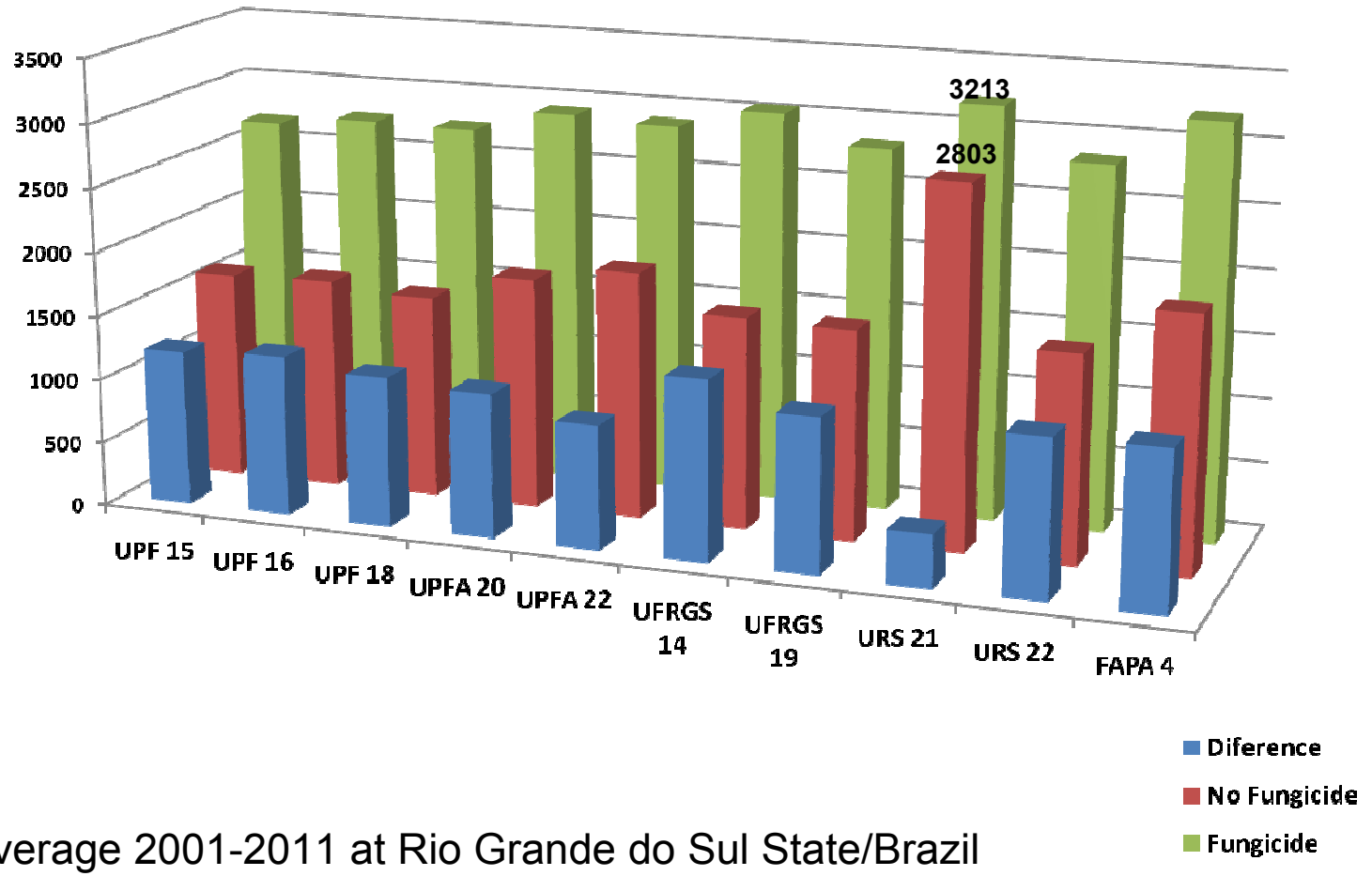
Flag leaf -2

Oat Brazilian varieties
Comparative grain yields: with and without fungicide spray



- Average 2001-2007 at Rio Grande do Sul State
- 3 to 6 locations / year (~ 5 locations / year)

Oat Brazilian varieties
Comparative grain yields: with and without fungicide spray



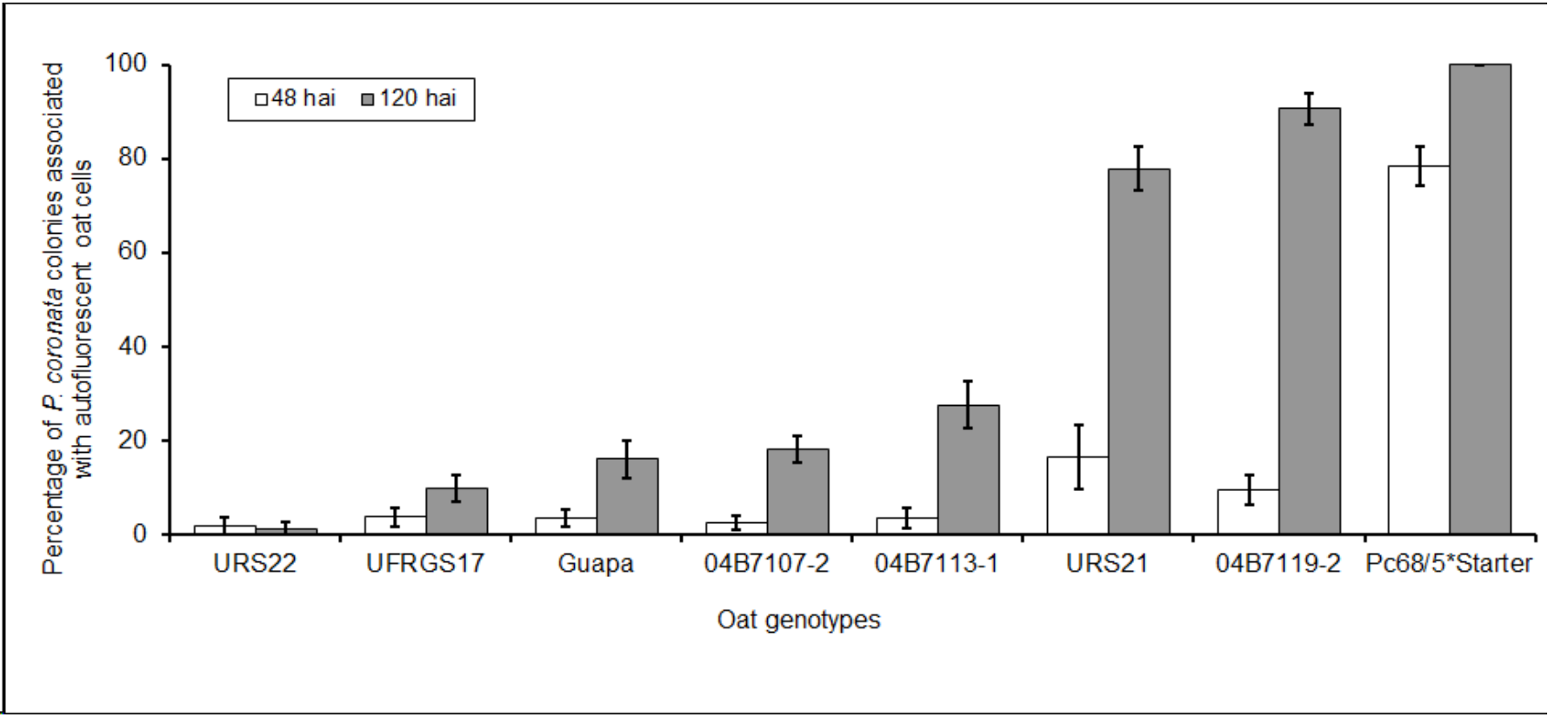
- Average 2001-2011 at Rio Grande do Sul State/Brazil
- 3 to 6 locations / year (~ 5 locations / year)

Epidemiological components of resistance to oat crown rust evaluated on field-grown adult plants and seedlings grown under controlled conditions in a growth chamber

Oat genotypes	Adult plants (field-grown)			Seedlings (growth chamber)		
	Area under disease progress curve normalized and corrected (AUDPCc) [b] Year			Pustule density	Latent period	
	2006	2007	2008	(pustulescm^{-2})[d]	(days)	
URS 22	907 a [a]	826 a [a]	1561 a [a]	115.7 a [a]	6.8[NS]	±0.101[f]
UFRGS 17	265 B	259 b	1089 a	135.3 a	7.0	±0.053
URS Guapa	–[c]	–[c]	470 b	94.2 a	6.9	±0.118
URS 21	43 C	112 c	46 c	13.3 c	7.5	±0.125
04B7113-1	7 D	5 e	7 d	36.5 bc	7.0	±0.000
Pc68/5*Starter	6 D	4 e	4 d	–[d]	–[d]	
04B7107-2	5 D	35 d	69 c	83.2 ab	6.9	±0.143
04B7119-2	4 D	–[c]	5 d	–[c]	–[c]	
CV %	11	8%	8	17	NA	

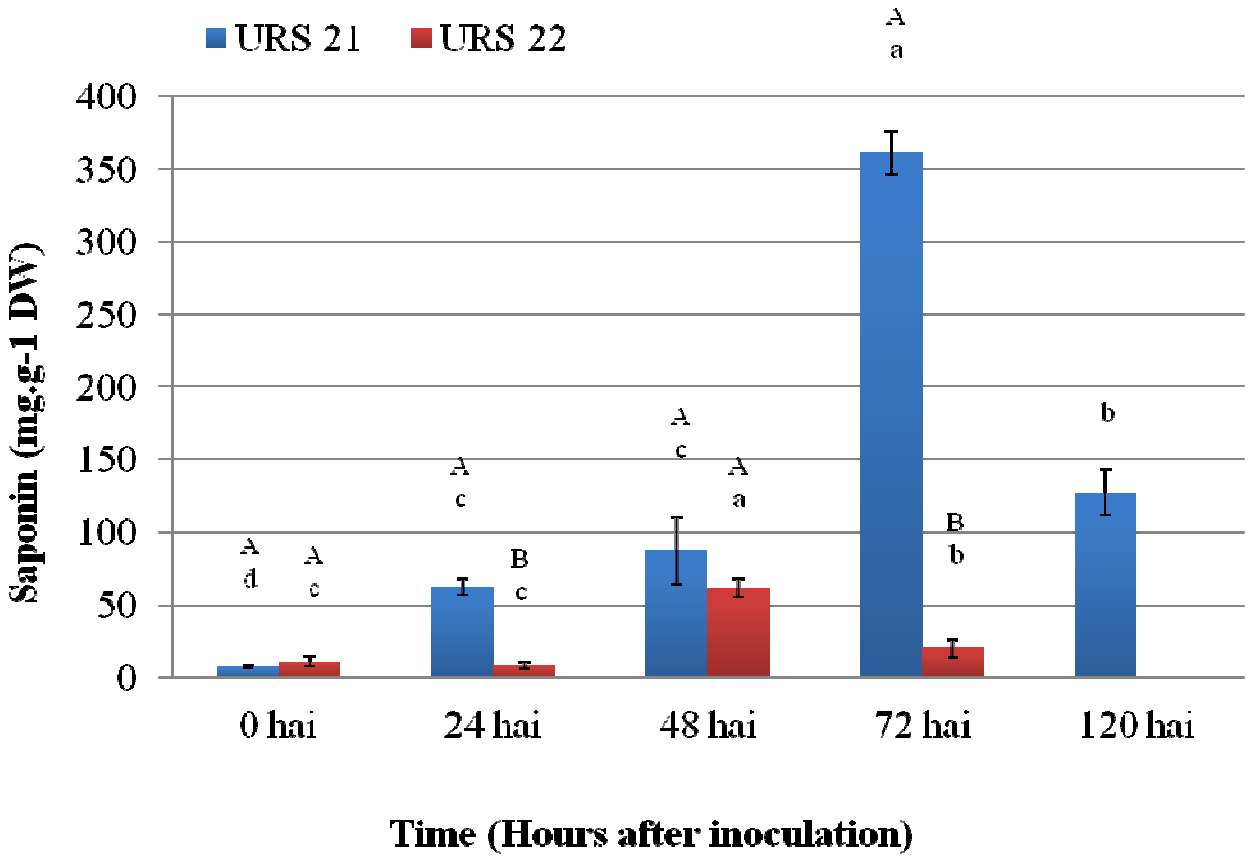
[a]Values with the same letter in a column are not significantly different by Duncan's test at the 5% probability level;

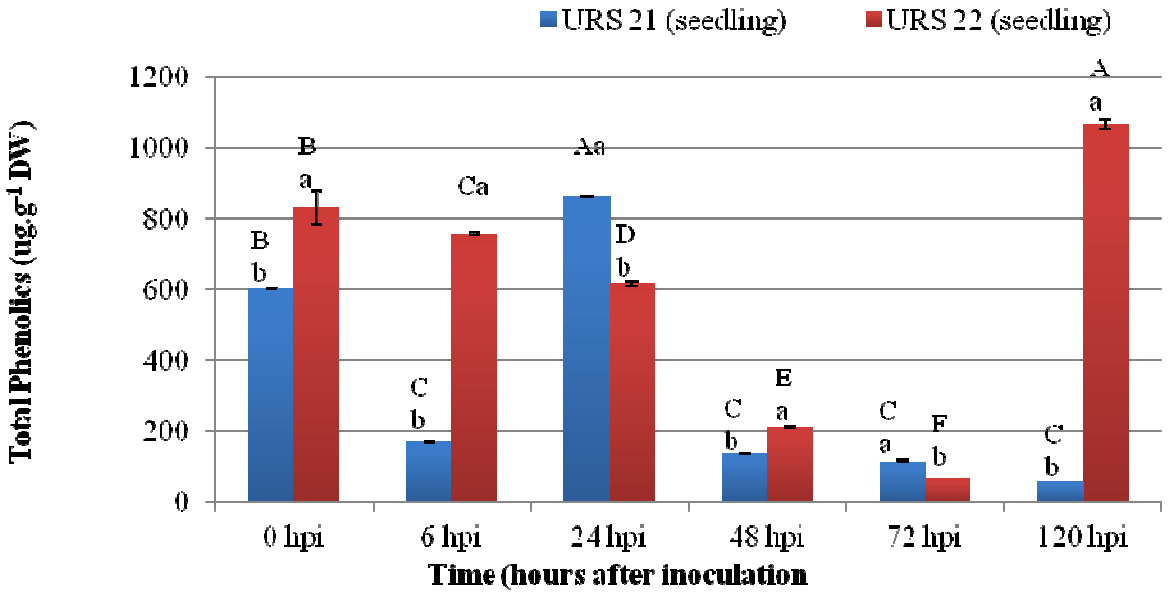
Percentage of P. coronata colonies associated with autofluorescent cells

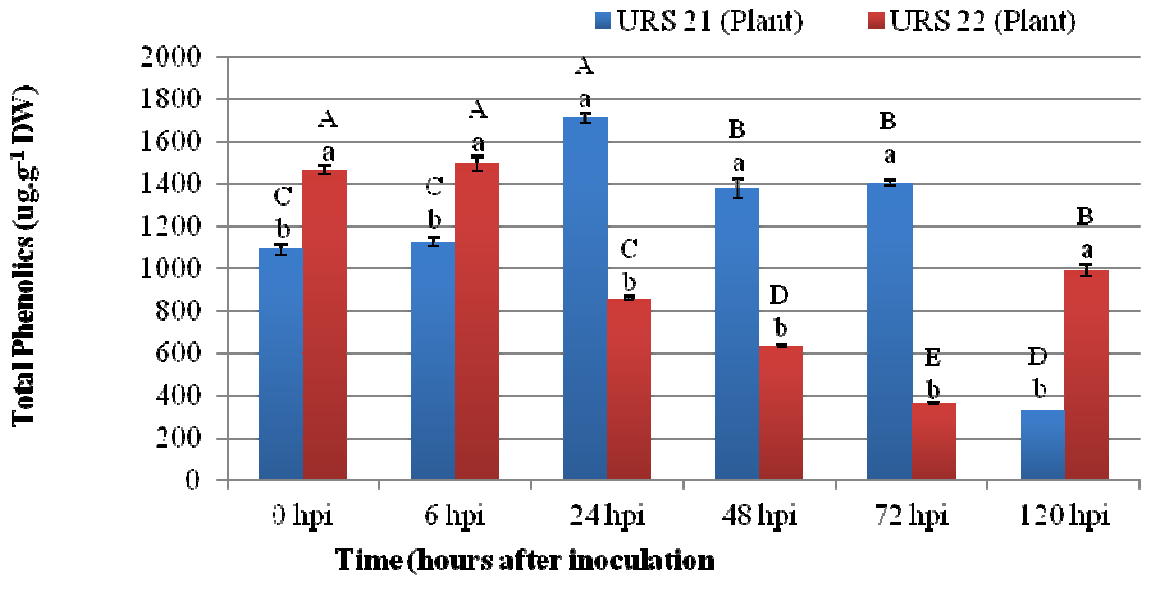


Infection Type seedling

Genotype	Infection Type			Phenotype
	Inoculation 1	Inoculation 2	Inoculation 3	
URS 22	3 3+ β	3 3+	3 3+	Suscetível
UFRGS 17	3 3+	3 3+	3 3+	Suscetível
URS Guapa	3 3+	3 3+	3 3+	Suscetível
04B7107-2	3- 3	3 3-	3 3 -	Suscetível
O4B7113-1	2N 2+ 3	2N 2+ 3	3- 3	Resistente
O4B7119-2	2+N 3-	2+N 1 ;	2N 1 3-	Resistente
URS 21	2 3- ;	1 ;	2 1 ;	Resistente
Pc68/5*Starter	0	0	0 (;)	Resistente


URS 21
URS 22
Saponin (mg.g-1 DW)
400
350
300
250
200
150
100
50
0
A
d
A
c
A
c
B
c
A
c
A
a
A
a
B
b
b
0 hai
24 hai
48 hai
72 hai
120 hai
Time (Hours after inoculation)

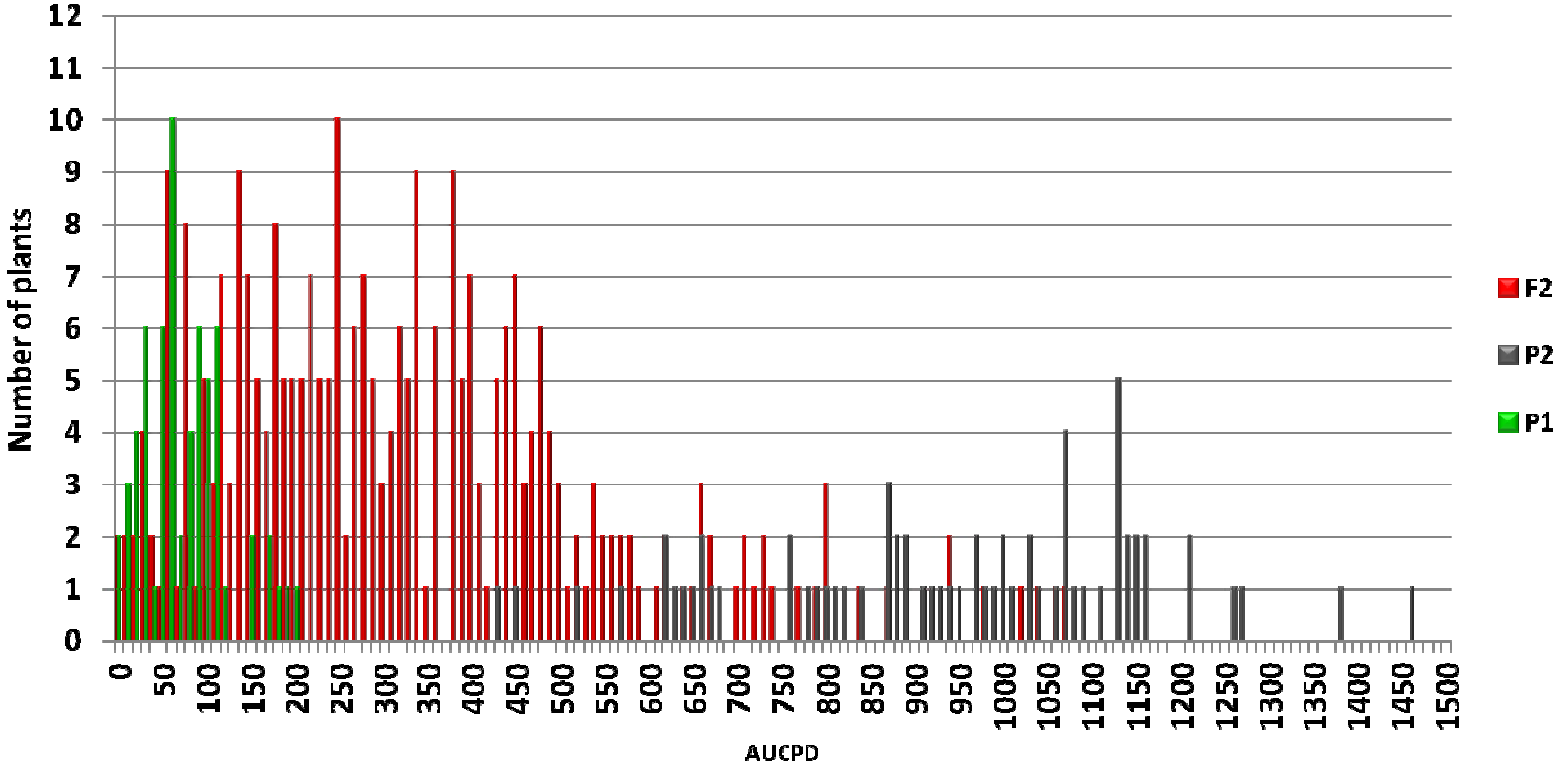

URS 21 (seedling)
URS 22 (seedling)
Total Phenolics (ug.g-1 DW)
1200
1000
800
600
400
200
0
0 hpi
6 hpi
24 hpi
48 hpi
72 hpi
120 hpi
Time (hours after inoculation


URS 21 (Plant)
URS 22 (Plant)
Total Phenolics (ug.g-1 DW)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0 hpi
6 hpi
24 hpi
48 hpi
72 hpi
120 hpi
Time (hours after inoculation

Genetic studies

	URS 21	URS 22	F1	F2	BC1	BC2
N.Ptas	79	68	78	289	66	52
Sev. Mín	0,5	50	5	0,5	3	20
Sev. Máx.	25	95	50	95	50	90
ASCPD Mín.	2	373,59	43,07	3,07	10,4	121,58
ASCPD Máx.	221,01	1225,6	469,09	900,05	481,59	825,67

Area Under Desease Progress Curve (AUDPC)

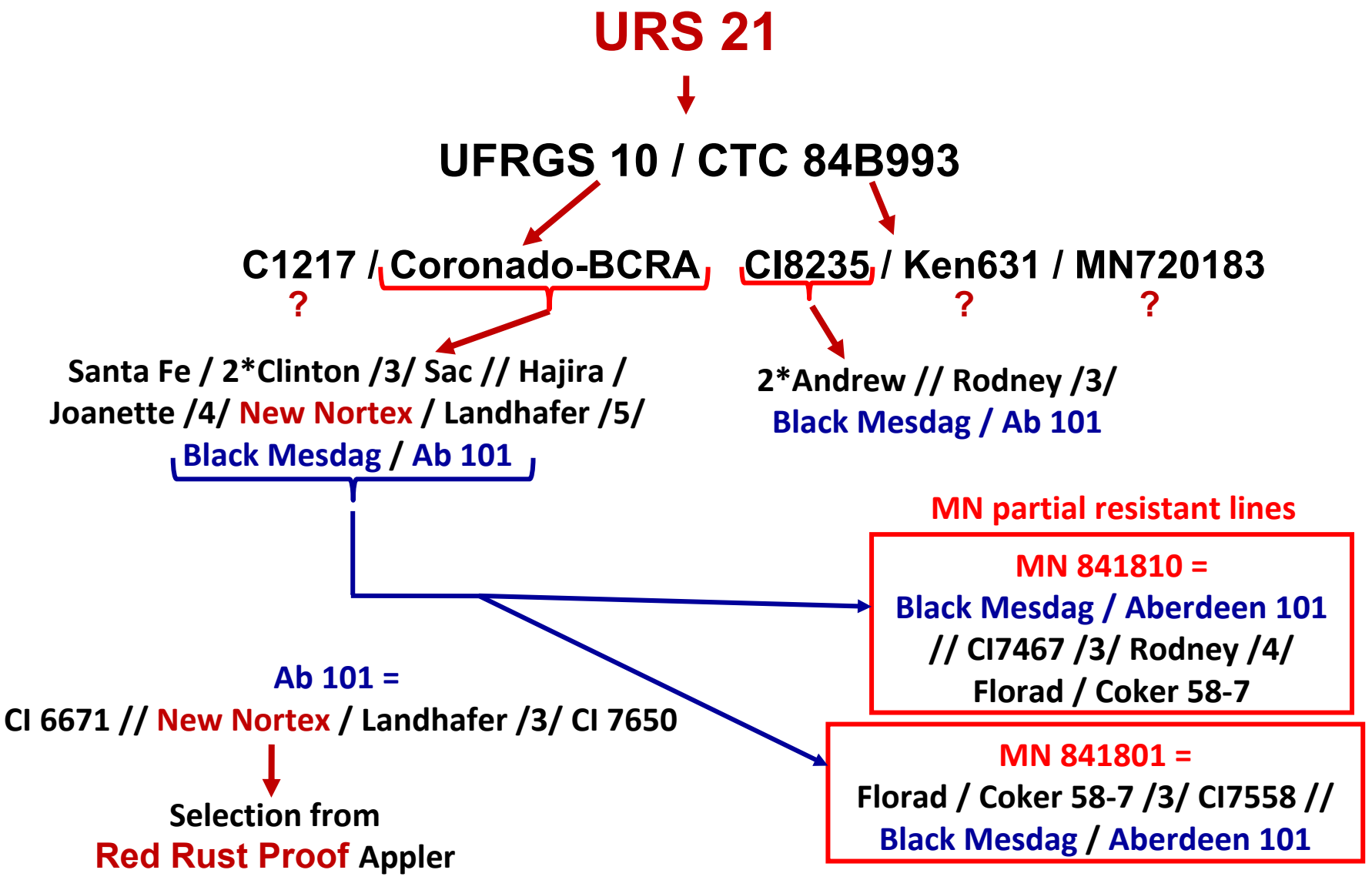


UFRGS

Genetic

5 locii (2 major effects)

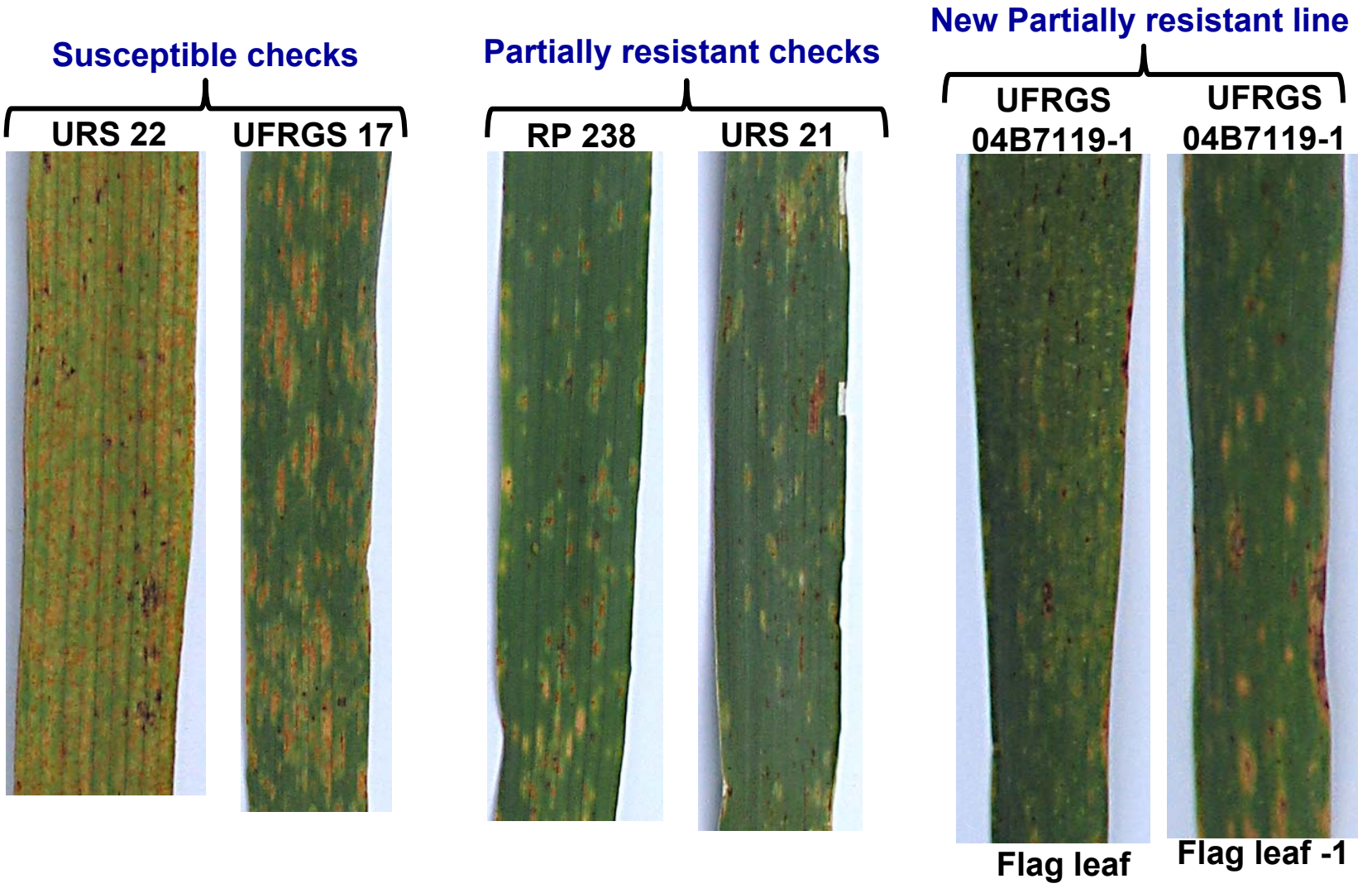
Um major loci recessive (for resistance)


URS 21
UFRGS 10 / CTC 84B993
C1217 / Coronado-BCRA
?
CI8235 / Ken631 / MN720183
? ?
Santa Fe / 2*Clinton /3/ Sac // Hajira /
Joanette /4/ New Nortex / Landhafer /5/
Black Mesdag / Ab 101
2*Andrew // Rodney /3/
Black Mesdag / Ab 101
MN partial resistant lines
MN 841810 =
Black Mesdag / Aberdeen 101
// CI7467 /3/ Rodney /4/
Florad / Coker 58-7
Ab 101 =
CI 6671 // New Nortex / Landhafer /3/ CI 7650
Selection from
Red Rust Proof Appler
MN 841801 =
Florad / Coker 58-7 /3/ CI7558 //
Black Mesdag / Aberdeen 101

General view of experiment including the new 34 partial resistant lines

UFRGS 952681 x UFRGS 17

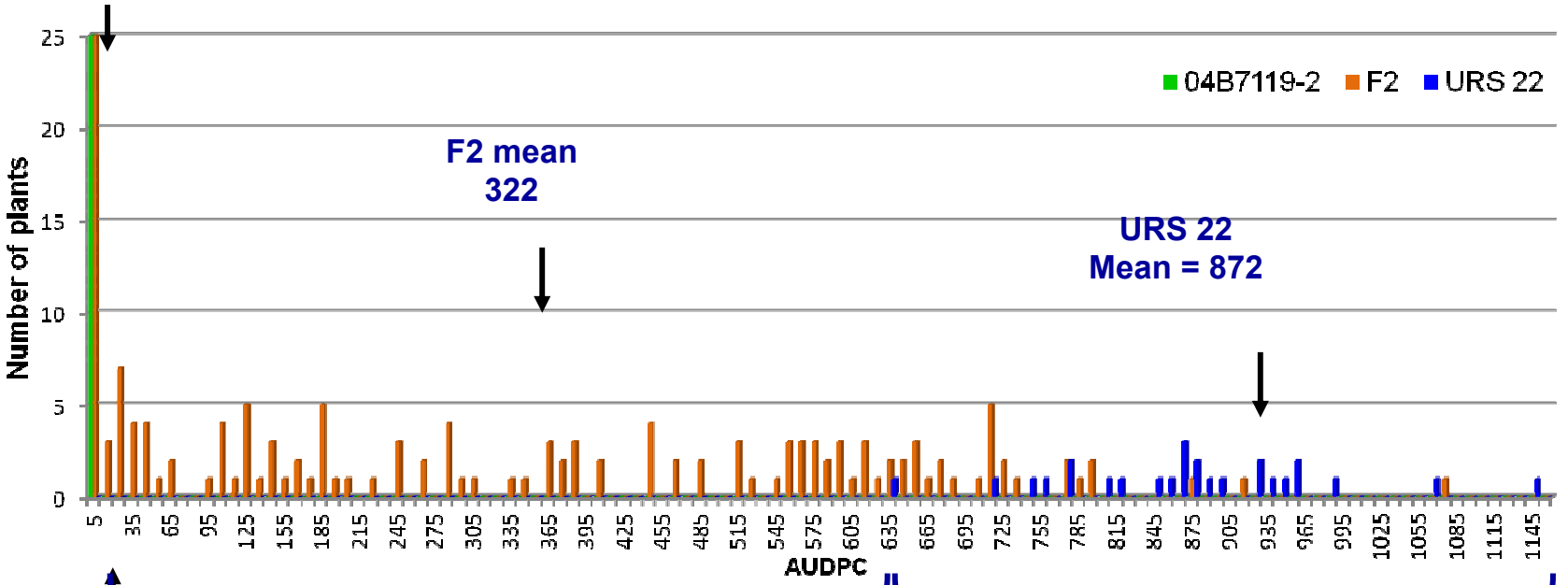
2006


Susceptible checks
URS 22
UFRGS 17
Partially resistant checks
RP 238
URS 21
New Partially resistant line
UFRGS 04B7119-1
UFRGS 04B7119-1
Flag leaf
Flag leaf -1

GENETICS OF THE PARTIAL RESISTANCE (PR)

- 6 F_2 populations → **PR Line** **x** **URS 22**
  Susc. parent
- Field Evaluation: sequential severity readings on individual plants
- Gene number estimated from AUDPC frequency distributions

Pop 6: UFRGS 04B7119-2 x URS 22



Resistant F_2:
25 plants
10, 9 ,8, 7
resistance alleles

Intermediate F_2:
103 plants
6, 5 ,4, 3
resistance alleles

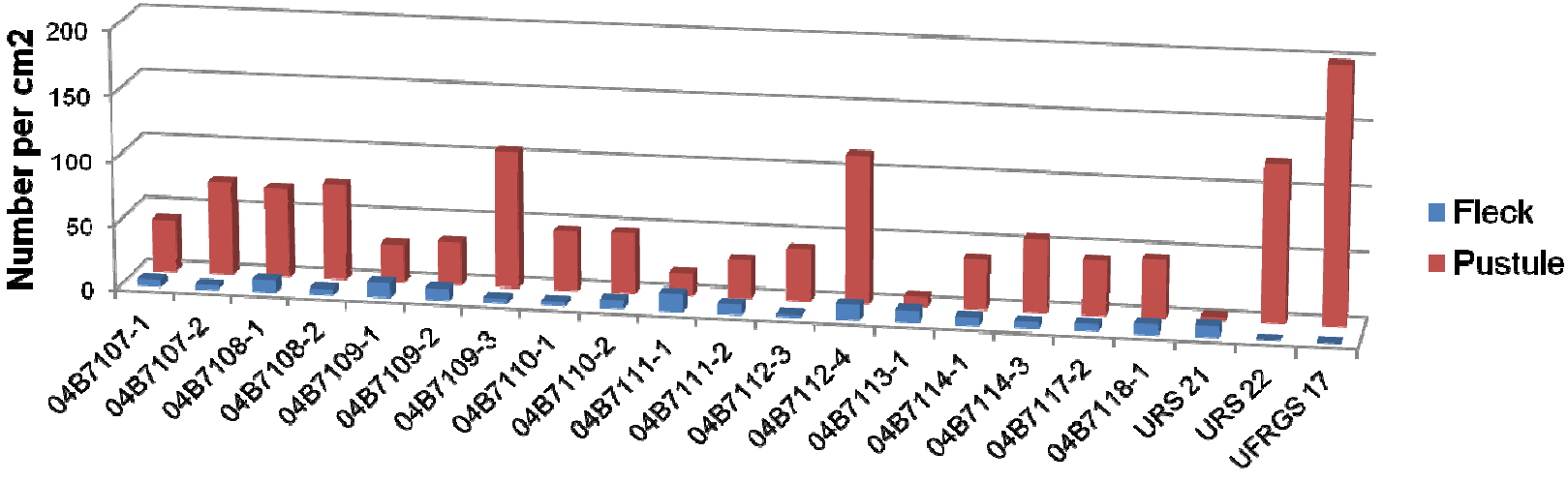
Susceptible F_2:
28 plants
2, 1, 0
resistance alleles

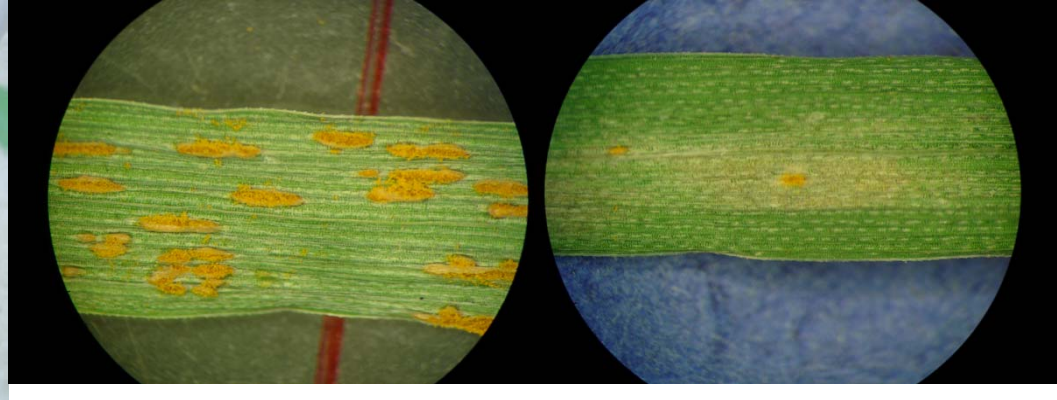
5 locos hypothesis
(additive model)

Class	OBS	EXP
Resist.	25	26.8
Interm.	103	102.4
Susc.	28	26.8
Total	156	156

x 2 = 0.1789
DF = 2
P = 0.91

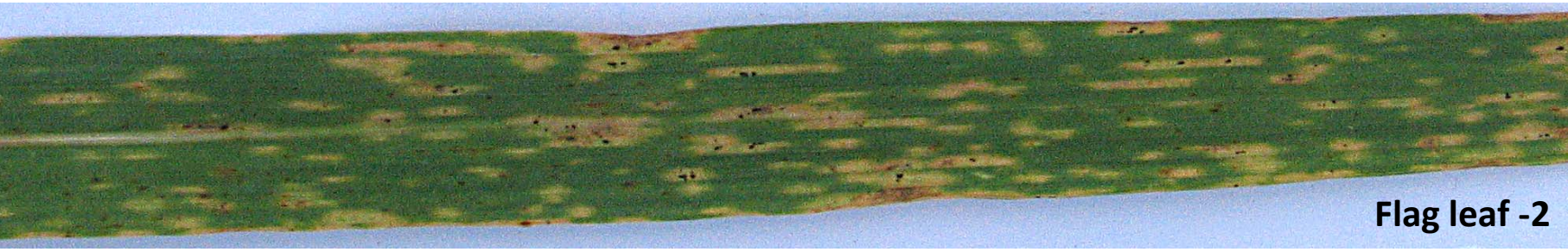
Partial resistant lines show { **Seedling resistance** / **Seedling susceptility**





Felipe Graichen, 2008 (unpublished)

2006 ➔ identified new set of crown rust partial resistant lines showing the necrosis/chlorosis phenotype



Derived from:

UFRGS 995078-2 x URS 21

UFRGS 10 X PAUL

C1217 / Coronado-BCRA

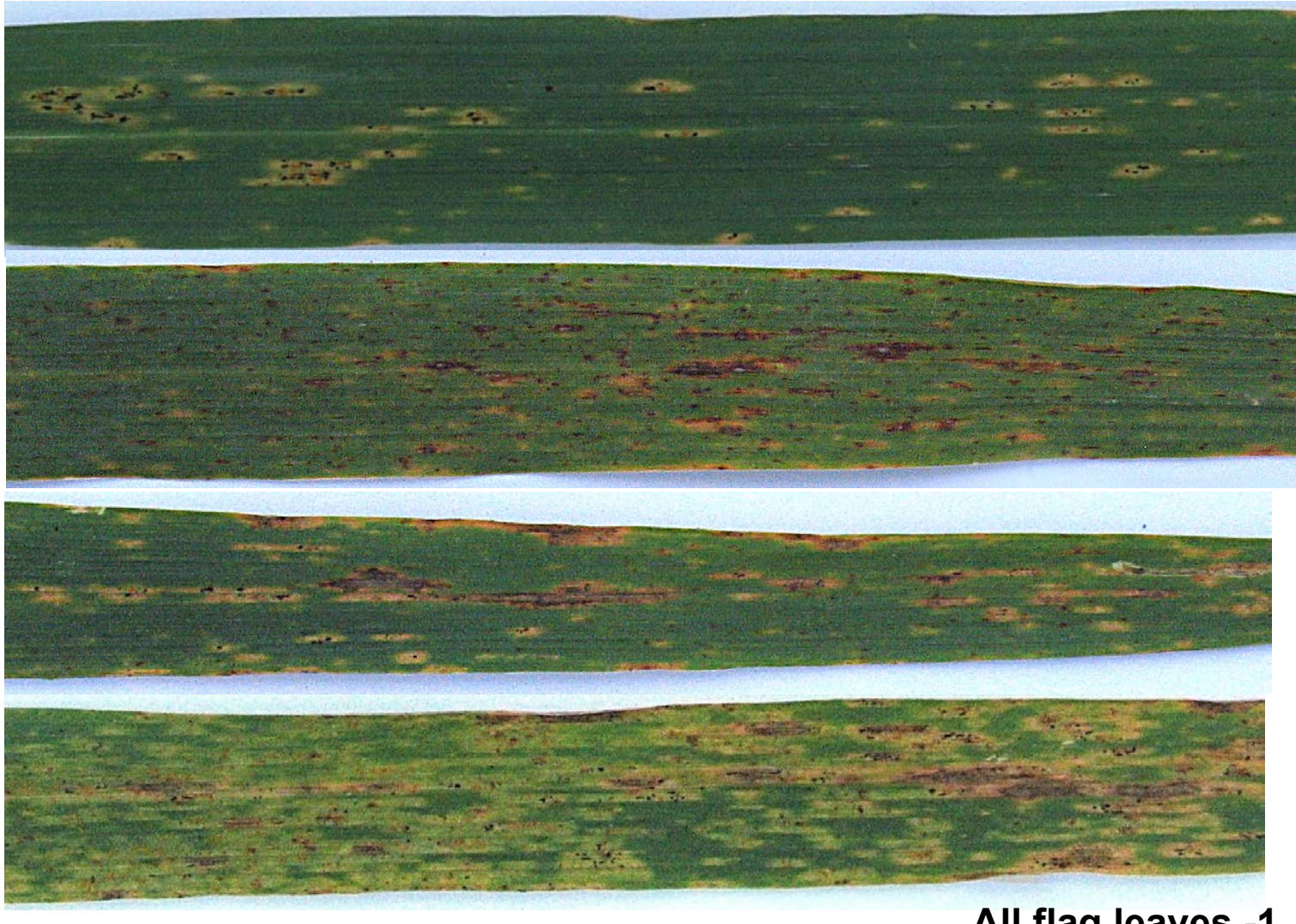
Santa Fe / 2*Clinton /3/ Sac // Hajira / Joanette /4/ New Nortex / Landhafer /5/ Black Mesdag / Ab 101

UFRGS 10 / CTC 84B993

CI8235 / Ken631 / MN720183

2*Andrew // Rodney /3/ Black Mesdag / Ab 101

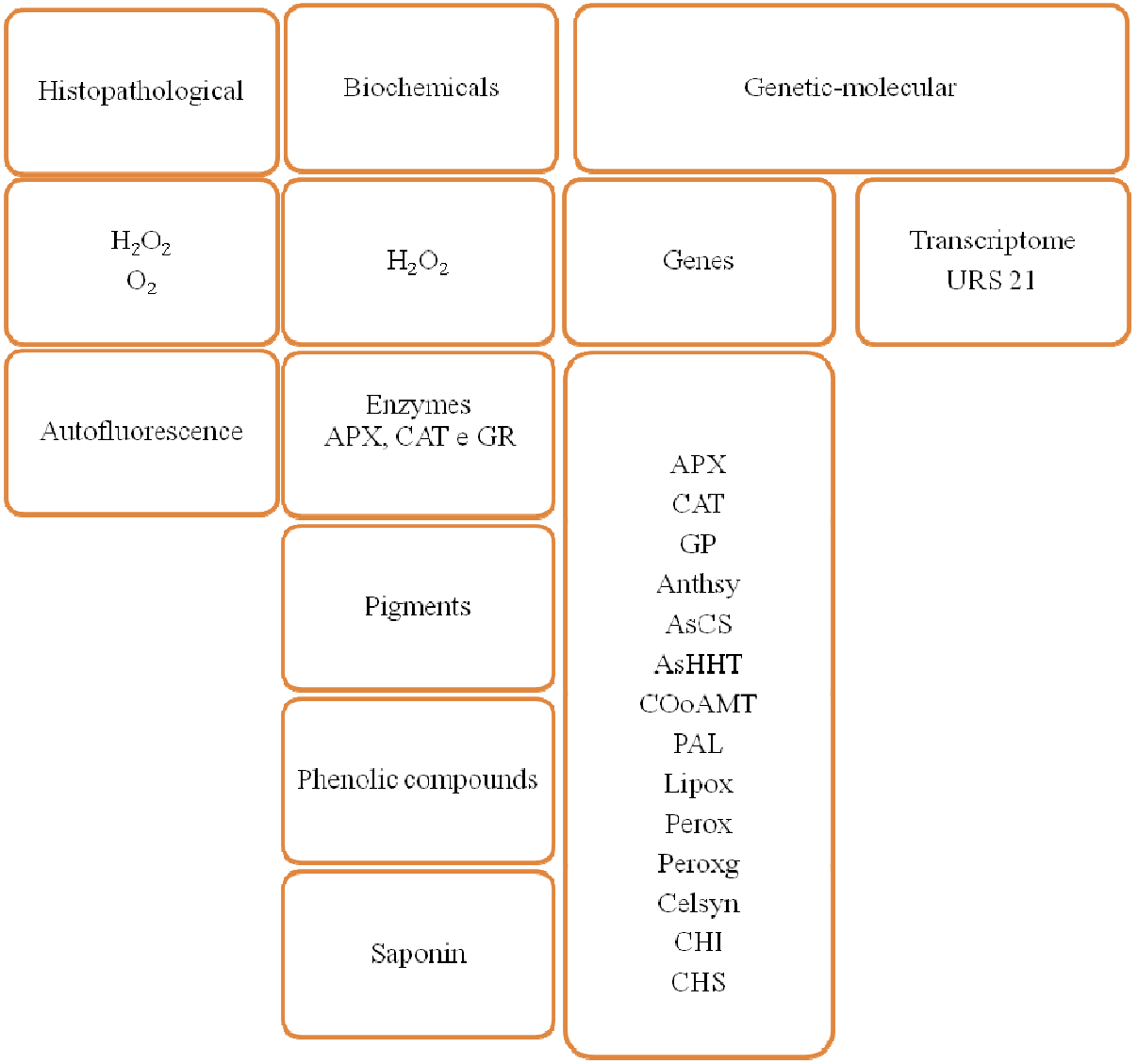
Different lines from cross
UFRGS 995078-2 x URS 21



All flag leaves -1

Release em 2012 the cultivar URS BRAVA with partial resistance.

Mechanisms


Histopathological
Biochemicals
Genetic-molecular
H_2O_2
O_2
H_2O_2
Genes
Transcriptome
URS 21
Autofluorescence
Enzymes
APX, CAT e GR
Pigments
Phenolic compounds
Saponin
APX
CAT
GP
Anthsy
AsCS
AsHHT
COoAMT
PAL
Lipox
Perox
Peroxg
Celsyn
CHI
CHS

Main conclusions

- There is a lot of variability and it is possible to select genotypes with PR to P. coronata even in hot spot environments;
- Different mechanism are at work from those used by major genes;
- Genetic complex , but with good heritabilities;
- Can erode with time;
- It works in field conditions;

THANK YOU