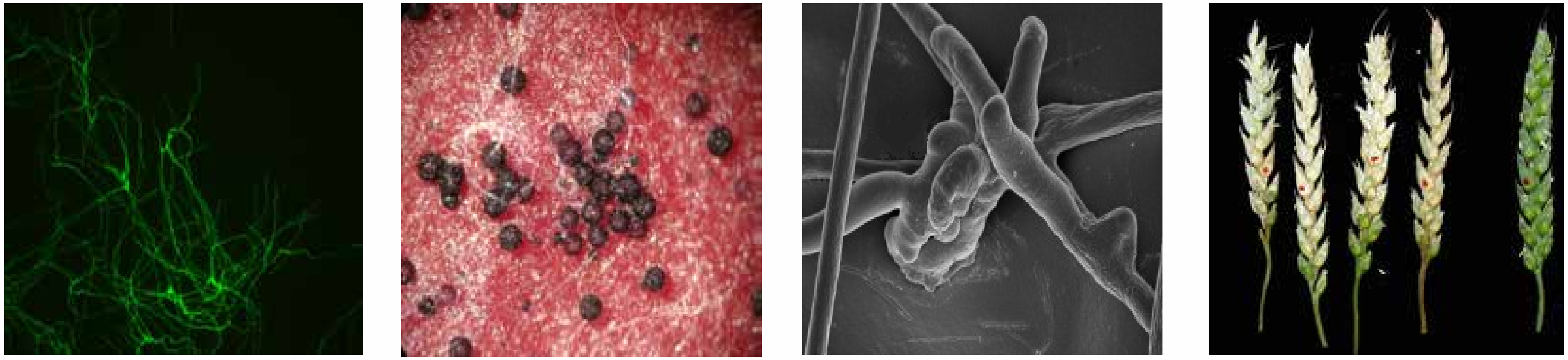
Intraspecies interaction of *Fusarium graminearum* contributes to reduced toxin production and virulence

Gopal Subramaniam
Sean Walkowiak



Research Focus

- Regulation of DON Biosynthesis
- Virulence/PAMPs
  Plant responses
- Mitigation Strategies

Intraspecies interaction of *Fusarium graminearum* contributes to reduced toxin production and virulence

A comparative genomics/proteomics approach

Fusarium Head Blight in Wheat, Barley…

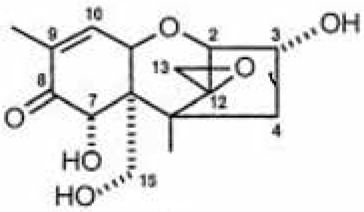
Ear rot of maize

- Reduced grain yield and quality
- Mycotoxin deposition

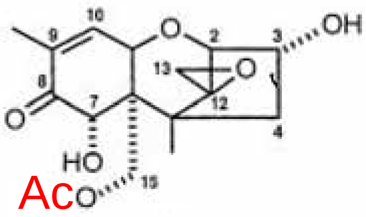
  Deoxynivalenol (DON)

  - **food and feed safety issues**
  - **potential export barrier**

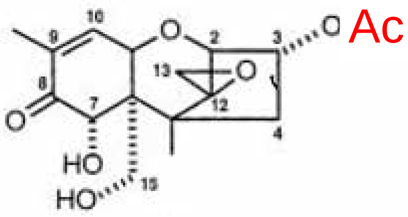
Head blight



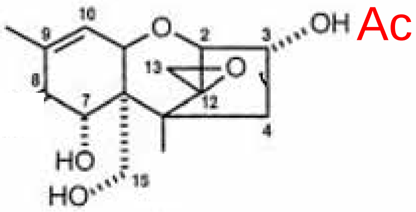
DON



15-ADON

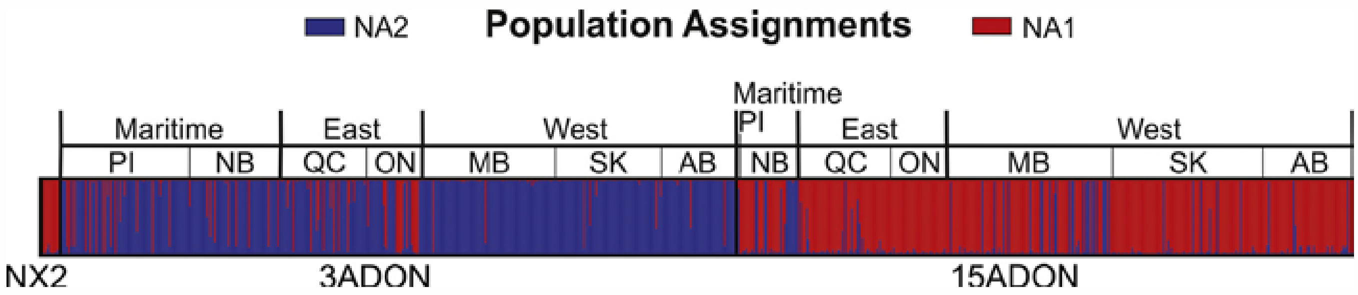


3-ADON

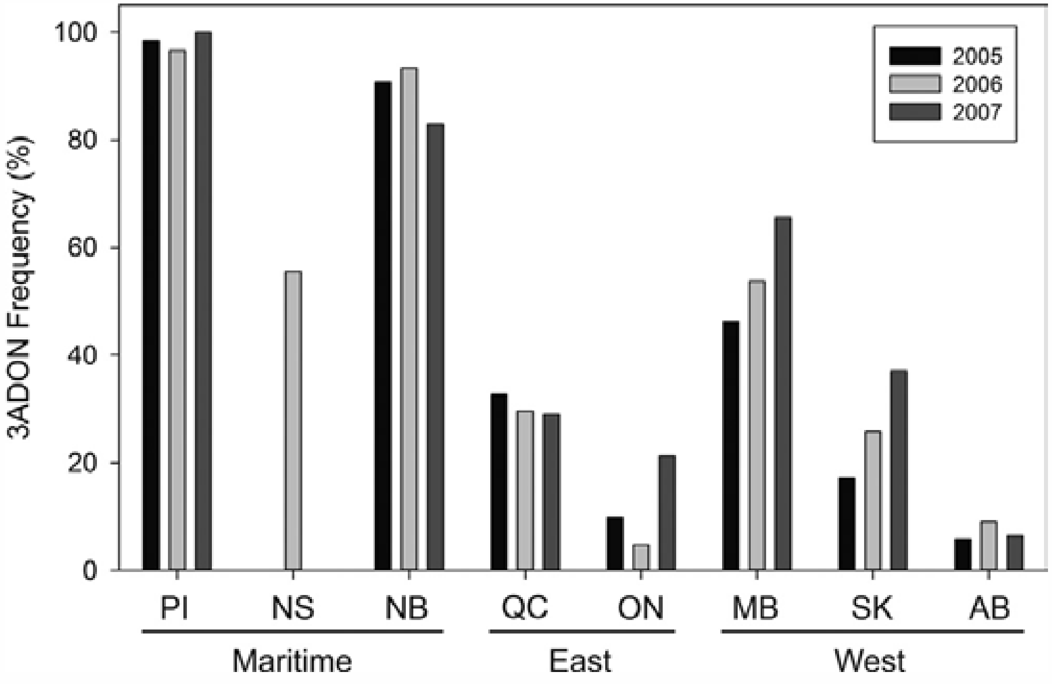


NX2

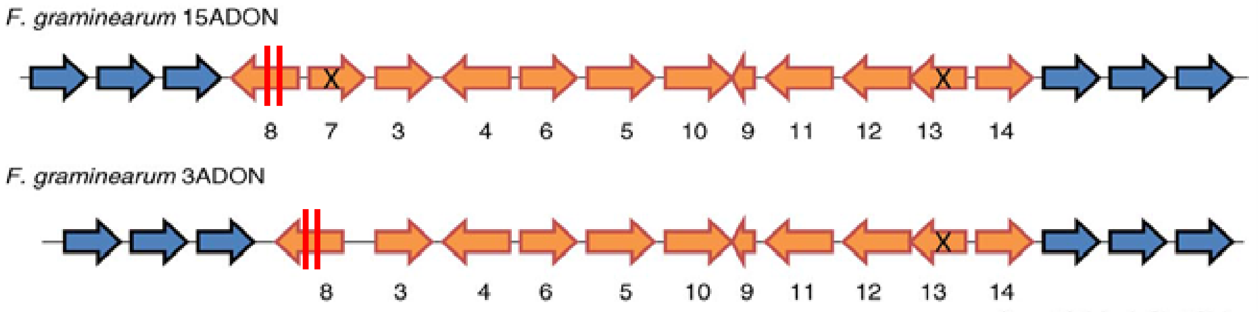
Distribution of *F. graminearum* across Canada



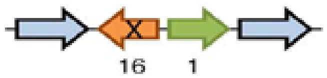
(Kelly et al., 2015)



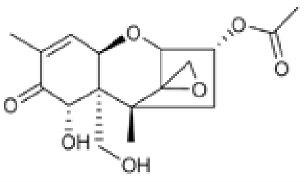
Genetics of Chemotypes



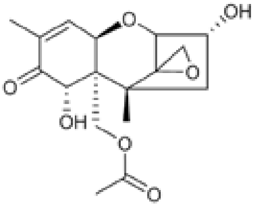
Current Opinion in Plant Biology



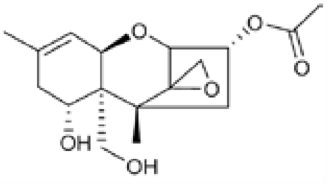
Rep & Kistler,2010



3-ADON

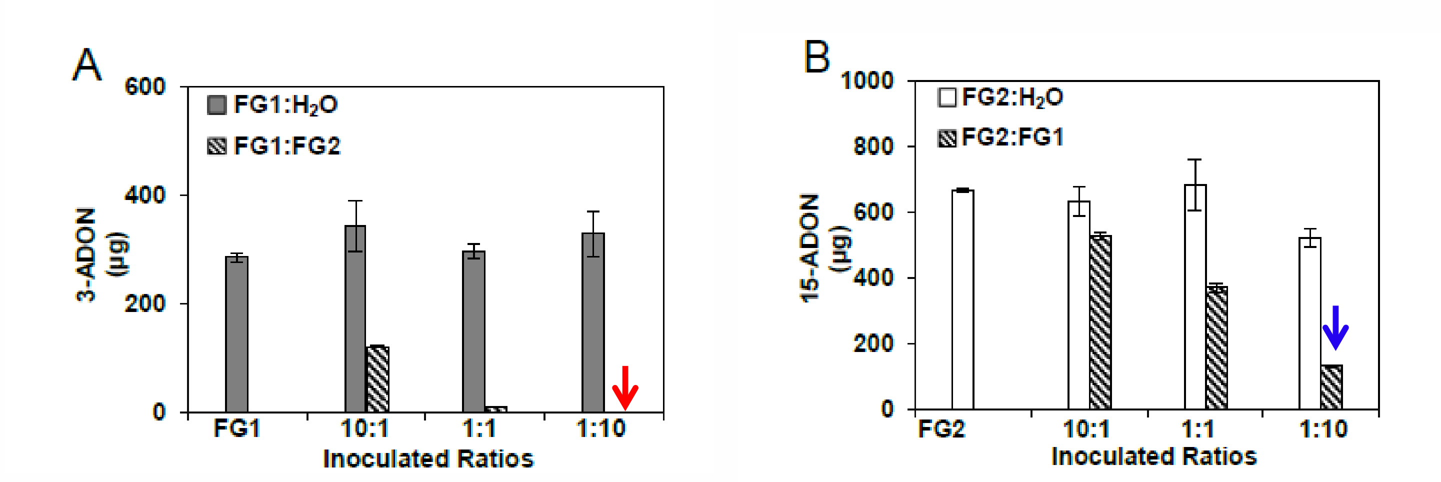


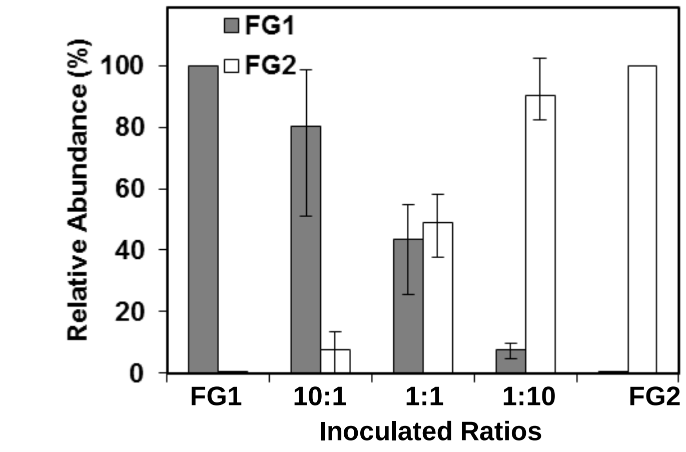
15-ADON



NX-2

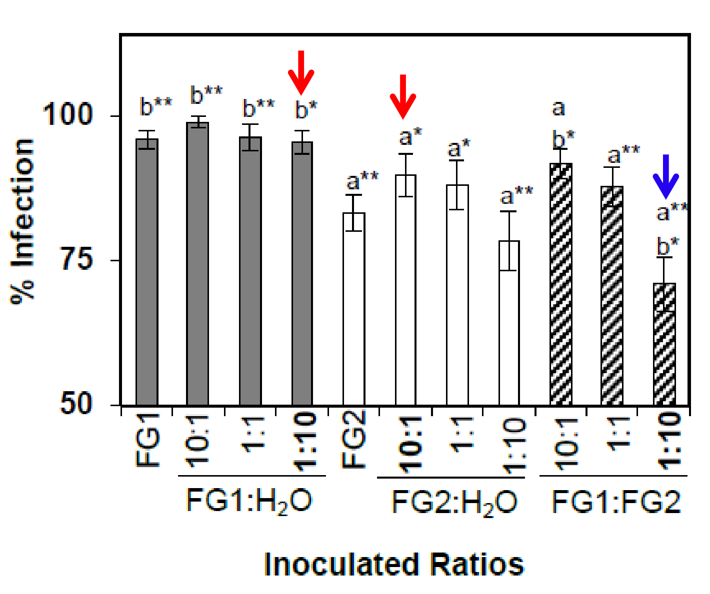
3-ADON (FG1) & 15-ADON (FG2)
Interfere each other *in Vitro*



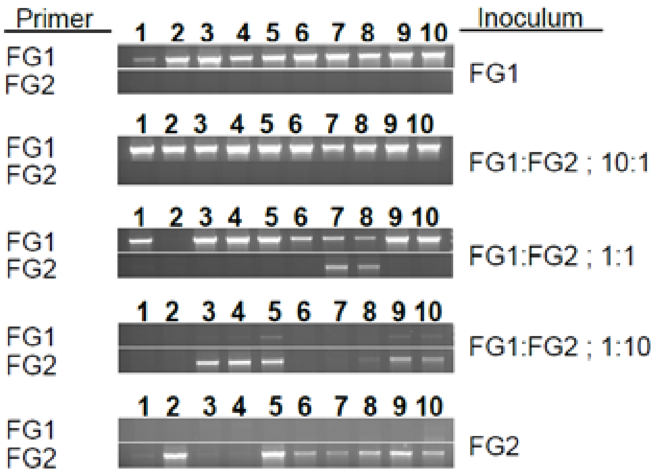


No displacement

3-ADON (FG1) & 15-ADON (FG2) Interfere during Infection



Virulence reduced during competition

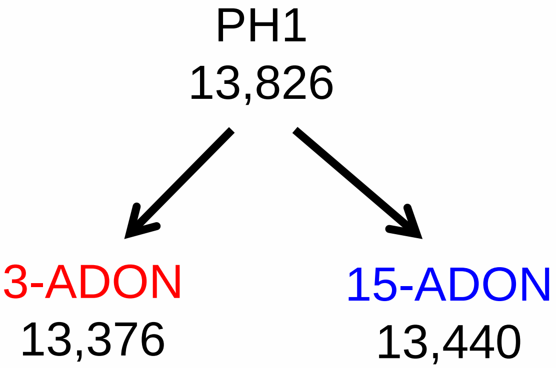


Chemotypes Co-habit

Walkowiak 2015; MPMI

Genome comparison between 3-ADON and 15-ADON

	PH-1	3-ADON	15-ADON
Method	Sanger	Illumina GAII	Illumina GAII
Genome Size (Mb)	36.6	36.6	36.5
Coverage (fold)	10x	144x	86x
Aligned bases (%)	97	97	98
GC %	48	48	48



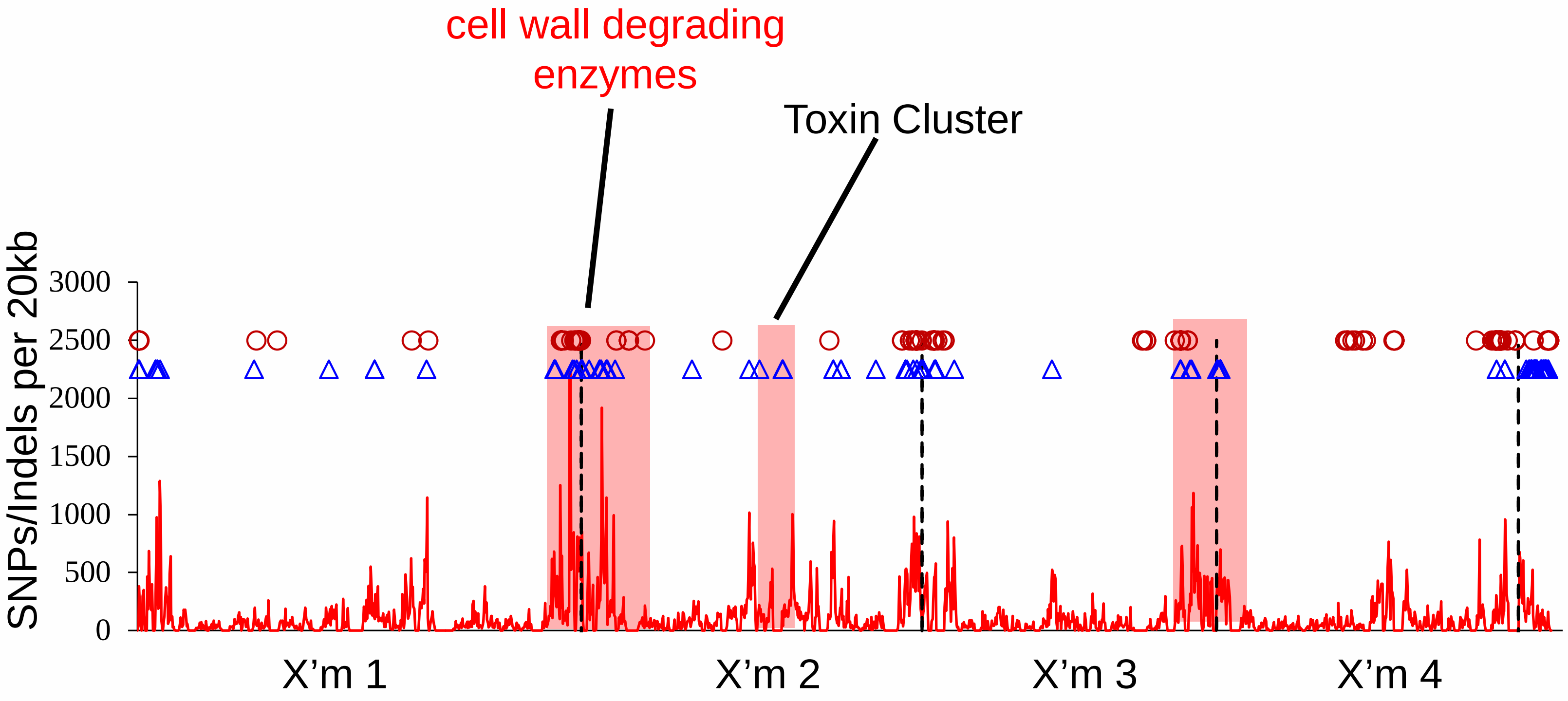
PH1
13,826

3-ADON
13,376

15-ADON
13,440

Genome alignment ~97%; Gene content ~ 97%

Gene features in 3-ADON and 15-ADON genomes

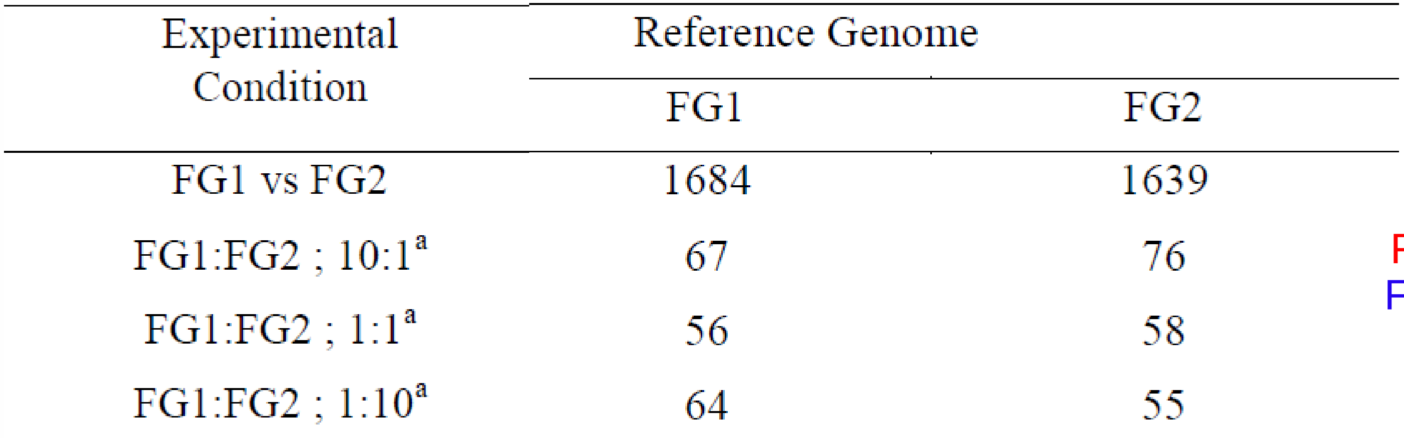


○ Poorly conserved genes in 3- ADON

△ Poorly conserved genes in 15- ADON

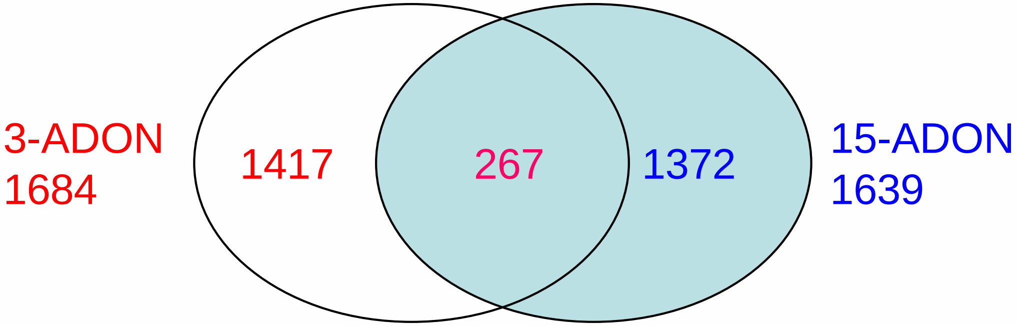
Walkowiak 2015; MPMI

Differential Expression Between Strains



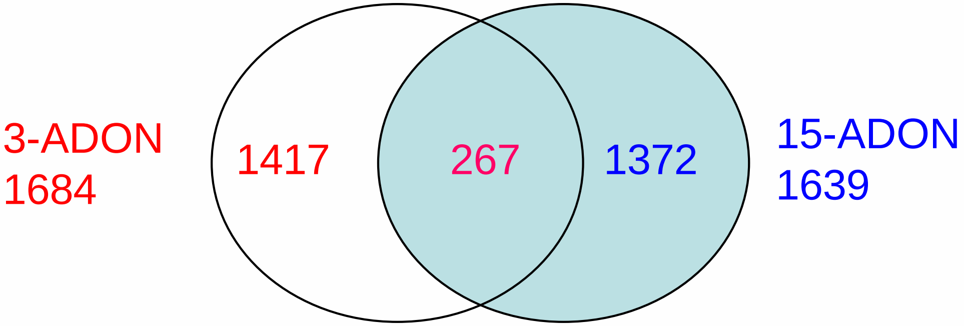
Experimental Condition	Reference Genome	
	FG1	FG2
FG1 vs FG2	1684	1639
FG1:FG2 ; 10:1[a]	67	76
FG1:FG2 ; 1:1[a]	56	58
FG1:FG2 ; 1:10[a]	64	55

FG1: 3-ADON
FG2: 15-ADON



Walkowiak 2015; MPMI

Functional categories of genes between two strains



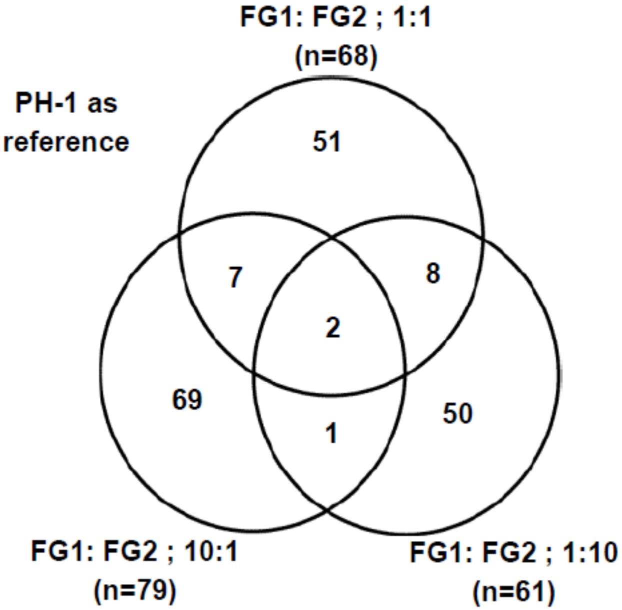
- 3-ADON dominated by metabolic genes (aspartate, pyruvate and aromatic families) exception: Phenylalanine metabolism)

- 15-ADON dominated cell-differentiation (eg: Hyphae formation); Electron transport

Differential Expression During Competition

Experimental Condition	Reference Genome	
	FG1	FG2
FG1 vs FG2	1684	1639
FG1:FG2 ; 10:1[a]	67	76
FG1:FG2 ; 1:1[a]	56	58
FG1:FG2 ; 1:10[a]	64	55

FG1: 3-ADON
FG2:15-ADON

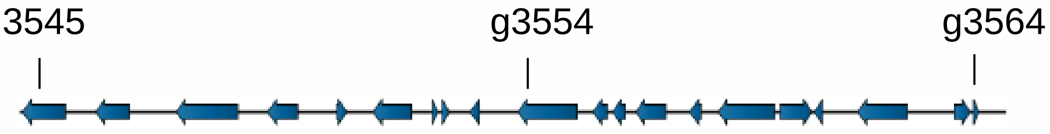


Functional categories: ALL in metabolism

Interesting Features of 3-ADON Strain

Contig 207:90 kb insert (20 genes)

(14/20 are differentially expressed)



	Gene	Predicted protein function
1	g3545	ankyrin repeat
2	g3546	Hypothetical protein
3	g3547	ATP-dependent DNA helicase
4	g3548	telomere-associated helicase
5	g3549	hypothetical protein
6	g3550	ANK superfamily
7	g3551	predicted protein
8	g3552	hypothetical protein
9	g3553	hypothetical protein
10	g3554	Unamed protein product

	Gene	Predicted protein function
11	g3555	hypothetical protein
12	g3556	hypothetical protein
13	g3557	hypothetical protein
14	g3558	hypothetical protein
15	g3559	hypothetical protein FOMG_17501
16	g3560	peptidase s8 family protein
17	g3561	major facilitator superfamily mfs-1
18	g3562	DDE superfamily endonuclease
19	g3563	predicted protein
20	g3564	uncharacterized proteinh

Genes of Contig 207 present in other 3-ADON Chemotypes

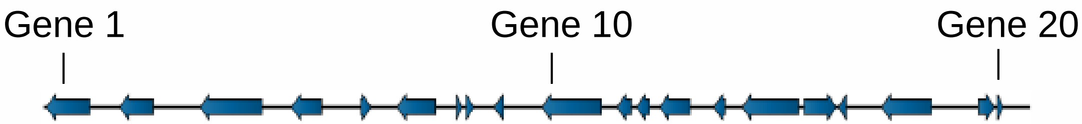
Strain	Chemotype	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	% Similarity	Origin
241165 (reference)	3	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	100	MB
S3BN-10-008	3	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	100	SK
TG2010_19/TG04_05	3	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	100	MB
TG2010_30/TG04_16	3	🟥	🟥	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	84	MB
LH-03A	3	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	84	NB
S6A-10-003	3	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	79	SK
S9B-10-001	3	🟥	🟥	🟩	🟥	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	79	SK
LH-14	3	🟩	🟩	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟥	🟥	🟥	🟩	🟩	🟩	63	QC
A6-10-001	3	🟥	🟥	🟩	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟩	58	AB
LH-04A	NX	🟥	🟩	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟩	🟩	🟥	53	NS
TG2010_50/TG04_36	3	🟥	🟩	🟥	🟥	🟩	🟩	🟥	🟩	🟥	🟩	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	42	MB
A5-10-005	3	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟩	🟩	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟩	🟥	🟥	42	AB
S7A-10-011	3	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	37	SK
A1-10-043	3	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟩	🟩	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	37	AB
A6-10-002	3	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	37	AB
A7-10-005	3	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	37	AB
LH-17	3	🟥	🟥	🟥	🟥	🟩	🟩	🟩	🟥	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟩	🟥	🟥	37	NB
A1-10-008	3	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	26	AB
LH-16	3	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟩	🟩	26	NB
LH-31	3	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟩	26	NB
A2-10-008	3	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	21	AB
A4-10-009	NX	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟩	🟥	🟥	21	AB
S4A-10-003	3	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	SK
S4B-10-003	3	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	SK
TG2010_63/TG04_49	3	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	MB
TG2010_69/TG04_55	3	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	5	MB
LH-23	3	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	5	NS

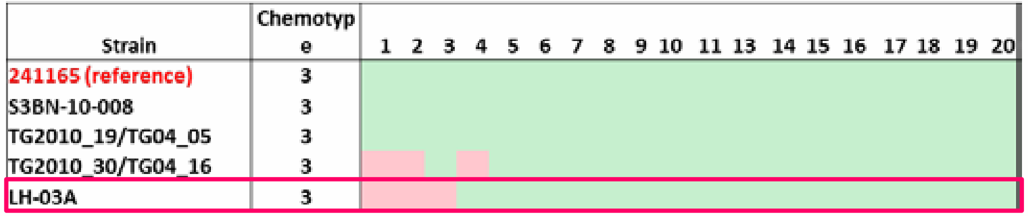
Genes of Contig 207 present in other 15-ADON Chemotypes

Strain	Chemotype	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20	% Similarity	Origin
241165 (reference)	3	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	100	MB
TG2010_61/TG04_47	15	🟥	🟥	🟩	🟥	🟥	🟩	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	68	MB
S4A-10-002	15	🟥	🟥	🟩	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	63	SK
TG2010_31/TG04_17	15	🟥	🟥	🟩	🟥	🟥	🟩	🟩	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟥	63	MB
TG2010_34/TG04_20	15	🟥	🟥	🟩	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	63	MB
A7-10-004	15	🟥	🟥	🟩	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	63	AB
S6B-10-009	15	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟩	🟥	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟥	47	SK
233423	15	🟩	🟩	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	32	KA
S6A-10-002	15	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	21	SK
TG2010_70/TG04_56	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟩	🟥	🟥	21	MB
A2-10-007	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟩	🟥	🟥	21	AB
A4-10-003	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	21	AB
LH-35	15	🟥	🟥	🟩	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	21	ON
S4B-10-004	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	SK
S7A-10-012	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	SK
TG2010_44/TG04_30	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	MB
A1-10-007	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟩	🟥	🟥	16	AB
A1-10-042	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	AB
A3-10-001	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	AB
LH-07	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	QC
LH-33	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	16	ON
S3BN-10-007	15	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	11	SK
S9B-10-002	15	🟥	🟥	🟥	🟥	🟥	▨	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	11	SK
TG2010_20/TG04_06	15	🟥	🟥	🟥	🟥	🟥	▨	🟥	🟥	🟥	🟩	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	11	MB
LH-19	15	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	11	NB
LH-21	15	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟩	🟥	🟥	11	NS
LH-13	15	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	5	QC
LH-26	15	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟩	🟥	🟥	🟥	🟥	🟥	🟥	🟥	5	NS

In planta expression of Contig 207 genes

Gene	Read Counts
1	0
2	0
3	0
4	0
5	0
6	539
7	0
8	27
9	44
10	51
11	196
12	6
13	242
14	0
15	873
16	833
17	1377
18	4
19	9
20	0





Strain	Chemotype	1	2	3	4	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20
241165 (reference)	3	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
S3BN-10-008	3	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
TG2010_19/TG04_05	3	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
TG2010_30/TG04_16	3	🟥	🟥	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
LH-03A	3	🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

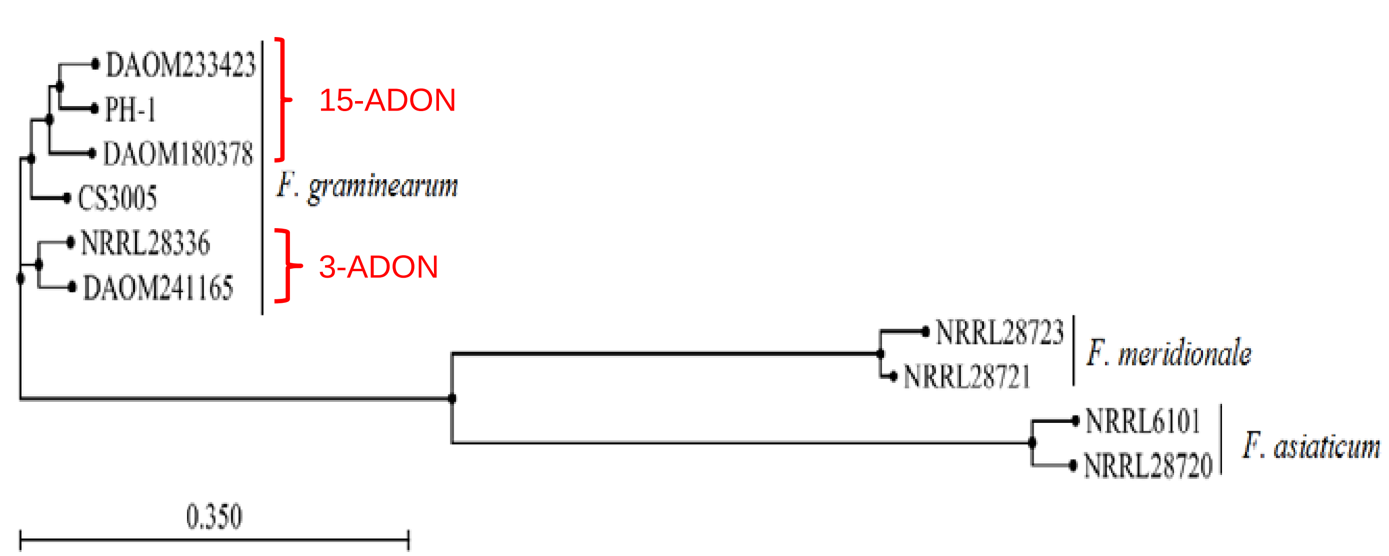
Follow-up: digital PCR expression during infection followed by knock-out studies

Fusarium Comparative Genomics

Isolate Accession	**Species**	**Toxin Type**	**Isolate Information**		**Pathology on Wheat**
			Host	**Location**	
PH-1; 31084	*F. graminearum*	DON, 15-ADON	Corn	Michigan	+++
180378	*F. graminearum*	DON, 15-ADON	Corn	Ontario	+++
29169	*F. graminearum*	DON, 15-ADON	Wheat	Kansas	+++
28336	*F. graminearum*	DON, 3-ADON	Wheat	Ohio	++
37440	*F. graminearum*	DON, 3-ADON	Wheat	Manitoba	+++
6101	*F. asiaticum*	DON, 3-ADON	Barley	Japan	-
28720	*F. asiaticum*	DON	Corn	Nepal	++
28723	*F. meridionale/F. asiaticum*	Niv	Corn	Nepal	+
28721	*F. meridionale*	Niv, 4-ANiv	Corn	Nepal	+

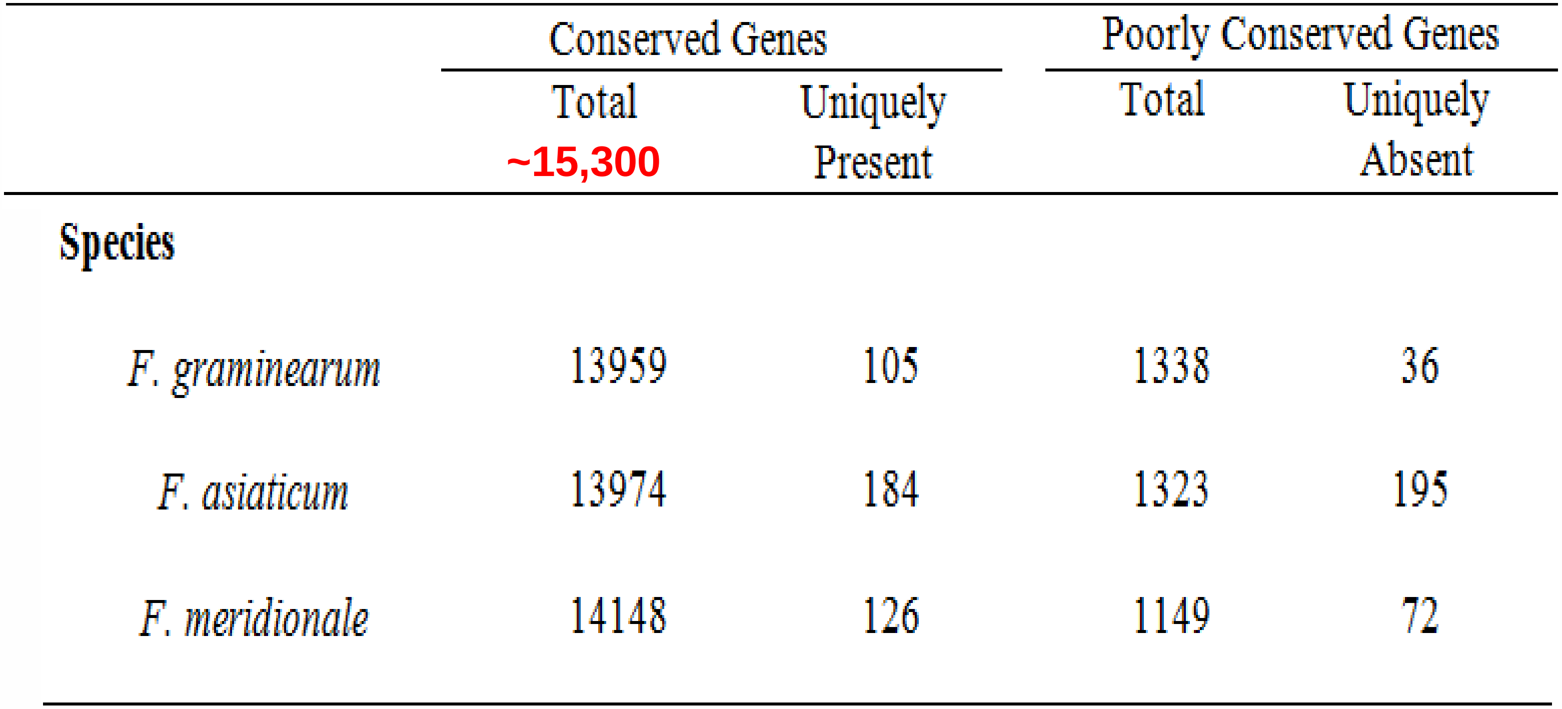
Goal: identify core (shared) genes of a species
+ its strain-specific (niche/host) genes

Fusarium Comparative Genomics



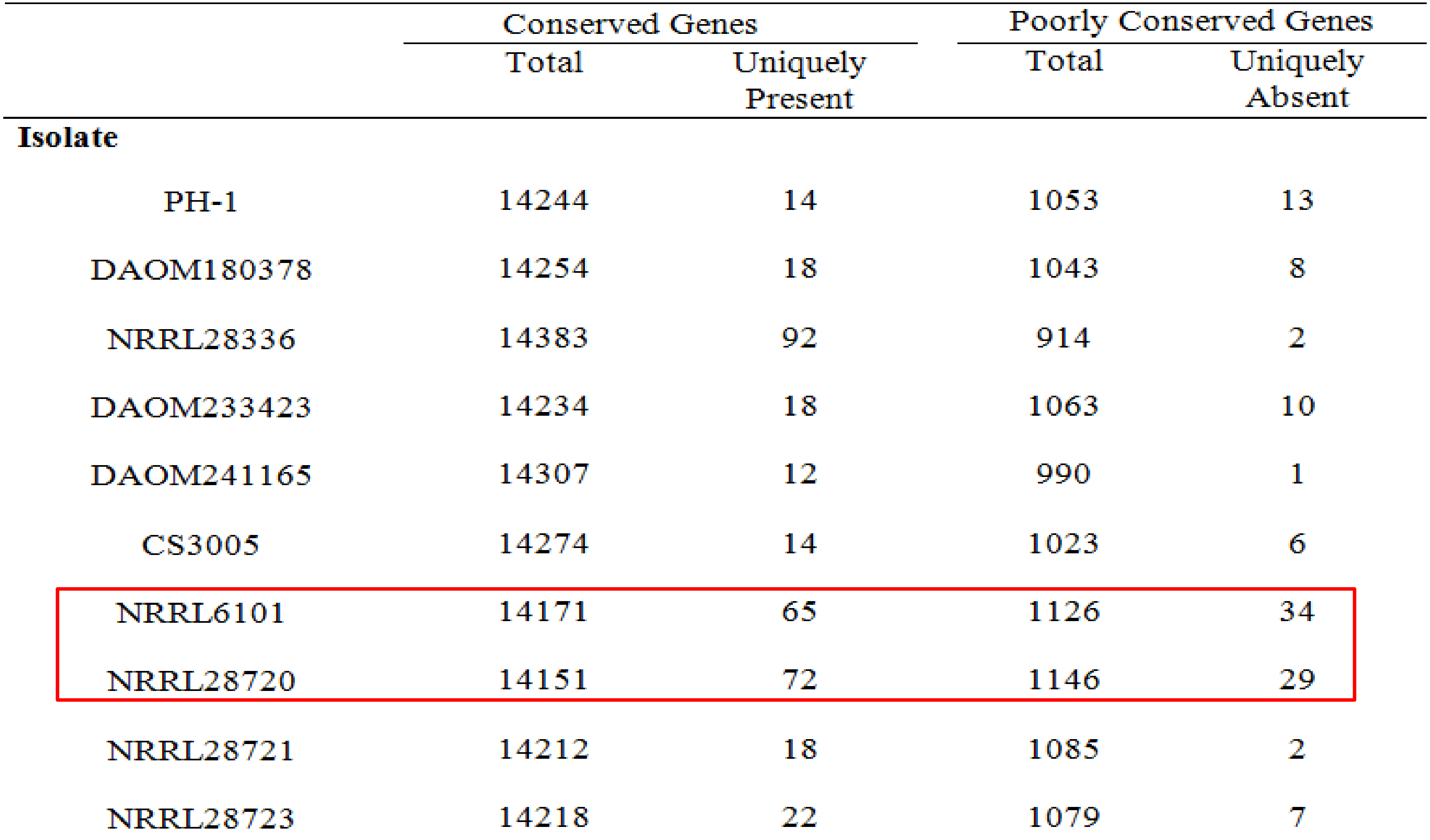
Phylogeny based on 90% identity (all genomes) and 700k SNPs/InDels

Pan Genome Identifies Core Genes



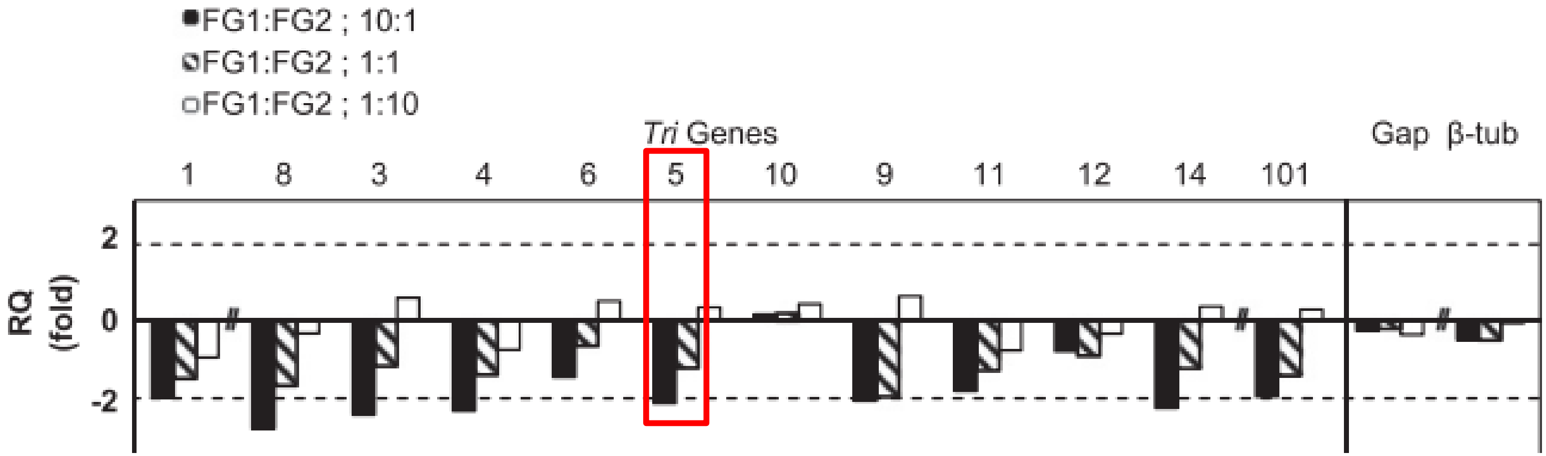
	Conserved Genes		Poorly Conserved Genes	
	Total ~15,300	Uniquely Present	Total	Uniquely Absent
Species				
F. graminearum	13959	105	1338	36
F. asiaticum	13974	184	1323	195
F. meridionale	14148	126	1149	72

Pan Genome Identifies Core Genes



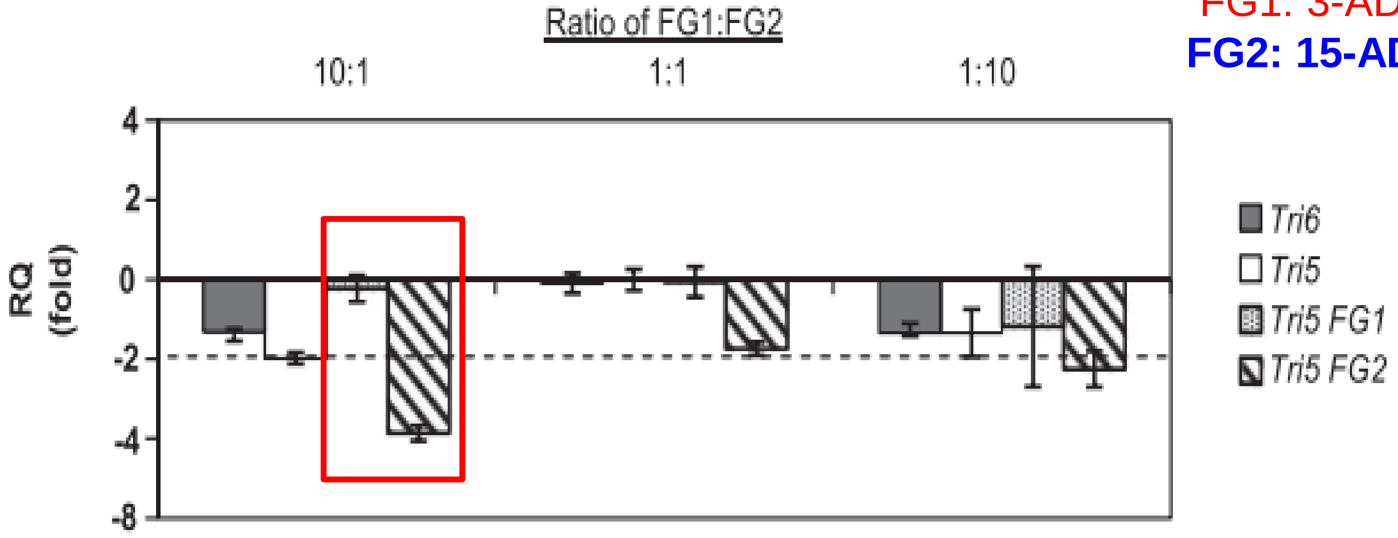
	Conserved Genes		Poorly Conserved Genes	
	Total	Uniquely Present	Total	Uniquely Absent
Isolate				
PH-1	14244	14	1053	13
DAOM180378	14254	18	1043	8
NRRL28336	14383	92	914	2
DAOM233423	14234	18	1063	10
DAOM241165	14307	12	990	1
CS3005	14274	14	1023	6
NRRL6101	14171	65	1126	34
NRRL28720	14151	72	1146	29
NRRL28721	14212	18	1085	2
NRRL28723	14218	22	1079	7

Validation of SNPs as Markers

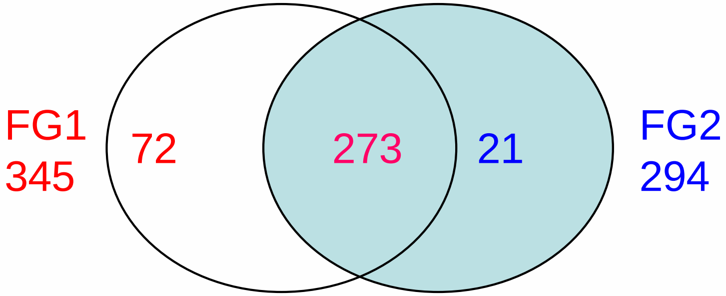


FG1: 3-ADON

FG2: 15-ADON



Pan genome Vs Pan Secretome Reveal Potential Function



FG1: 3-ADON
FG2:15-ADON

Gene Name	Source/descriptor	SNPs per kb
FGSG_04546	related to serine-type carboxypeptidase f precursor	115
FGSG_12548	related to feruloyl esterase B precursor	114
FGSG_04527	related to carboxypeptidase	114
FGSG_11399	related to oxidoreductase	109
FGSG_07678	related to acid phosphatase Pho610	100
FGSG_00100	related to 6-hydroxy-d-nicotine oxidase	100
FGSG_02918	related to aspartic proteinase, pepstatin-sensitive	100
FGSG_16186	related to LPL lysophospholipase precursor	89
FGSG_02342	probable cutinase 1 precursor	86

Summary:

Interaction between Fusarium may be common

- Cautious about interpreting phenotypes

Comparative genomics

- Identify genetic differences that may account for some of the diversity within *Fusarium graminearum* genomes
- Pan-Genome: fast/slow evolving genes
  design markers
  Virulence factors
  PAMPs

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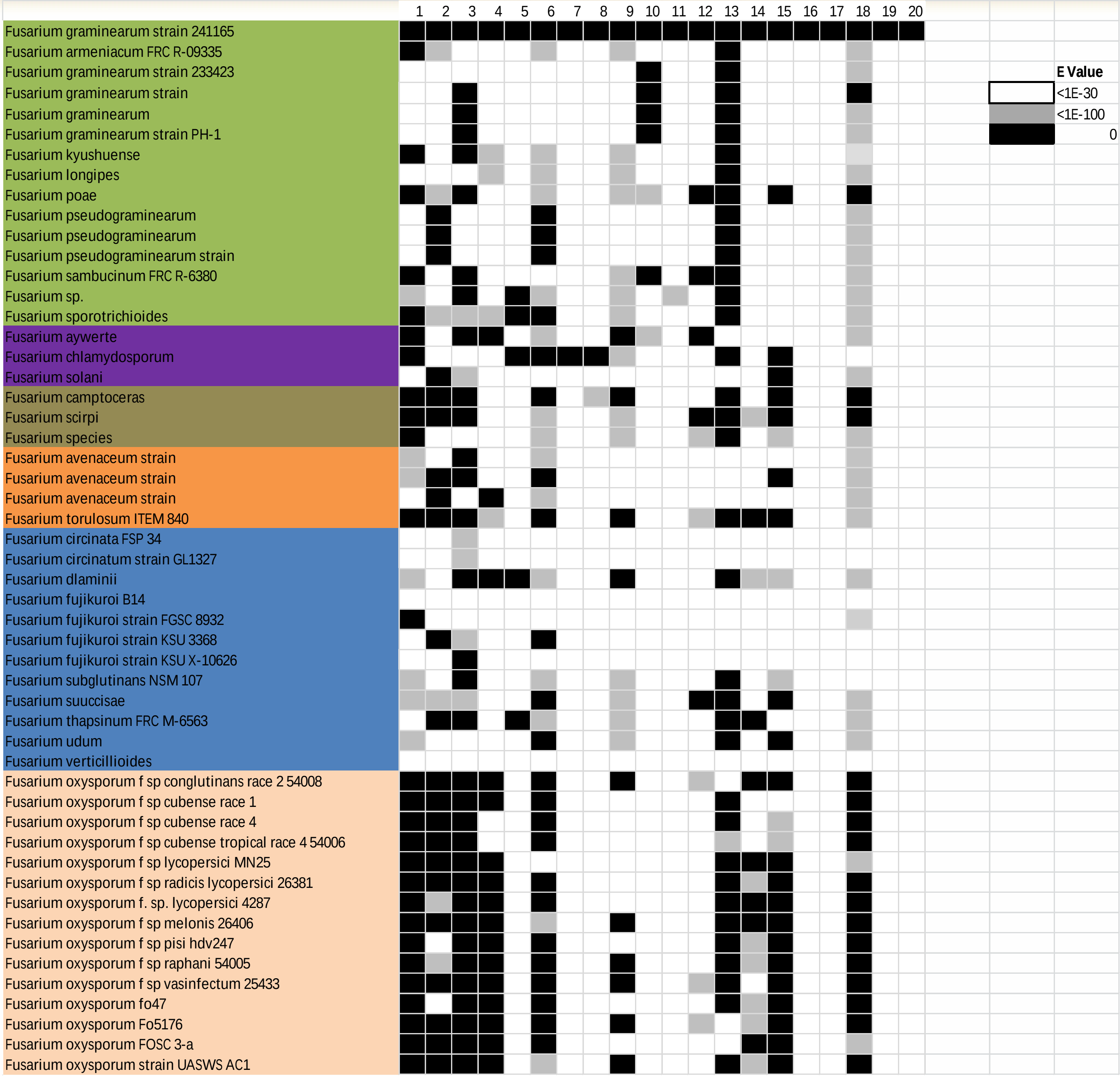
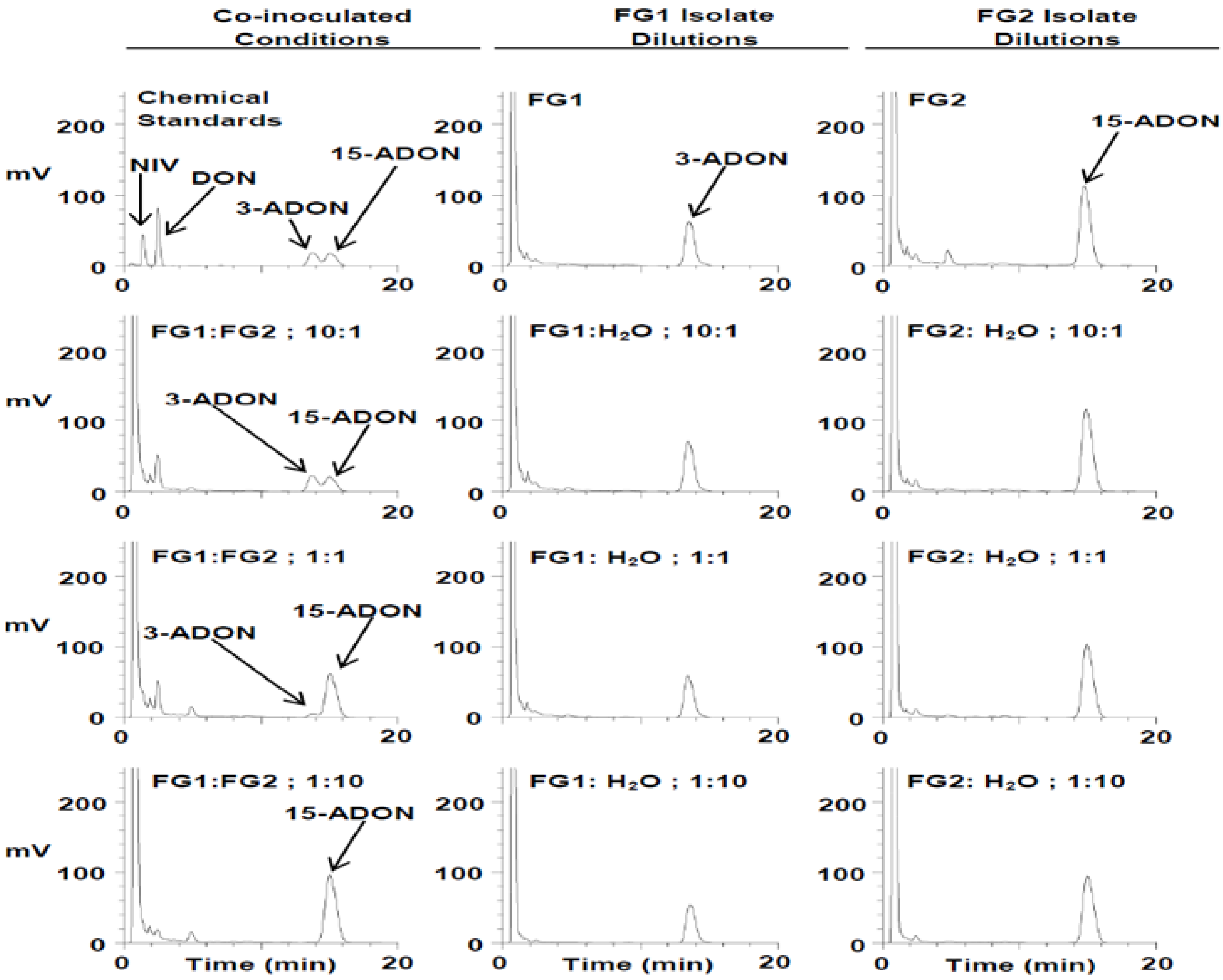
Genes within Contig 207 present in other Fusarium



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fusarium graminearum strain 241165	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Fusarium armeniacum FRC R-09335	■	▨				▨			▨				■					▨		
Fusarium graminearum strain 233423										■			■					▨		
Fusarium graminearum strain			■							■			■					■		
Fusarium graminearum			■							■			■					▨		
Fusarium graminearum strain PH-1			■							■			■					▨		
Fusarium kyushuense	■		■	▨		▨			▨				■					▨		
Fusarium longipes				▨		▨			▨				■					▨		
Fusarium poae	■	▨	■			▨			▨	▨		■	■		■			■		
Fusarium pseudograminearum		■				■							■					▨		
Fusarium pseudograminearum		■				■							■					▨		
Fusarium pseudograminearum strain		■				■							■					▨		
Fusarium sambucinum FRC R-6380	■		■						▨	■		■	■					▨		
Fusarium sp.	▨		■		■	▨			▨		▨		■					▨		
Fusarium sporotrichioides	■	▨	▨	▨	■	■			▨				■					▨		
Fusarium aywerte	■		■	■		▨			■	▨		■						▨		
Fusarium chlamydosporum	■				■	■	■	■	▨				■		■					
Fusarium solani		■	▨												■			▨		
Fusarium camptoceras	■	■	■			■		▨	■				■		■			■		
Fusarium scirpi	■	■	■			▨			▨			■	■	▨	■			■		
Fusarium species	■					▨			▨			▨	■		▨			▨		
Fusarium avenaceum strain	▨		■			▨												▨		
Fusarium avenaceum strain	▨	■	■			■									■			▨		
Fusarium avenaceum strain		■		■		▨												▨		
Fusarium torulosum ITEM 840	■	■	■	▨		■			■			▨	■	■	■			▨		
Fusarium circinata FSP 34			▨																	
Fusarium circinatum strain GL1327			▨																	
Fusarium dlaminii	▨		■	■	■	▨			■				■	▨	▨			▨		
Fusarium fujikuroi B14																				
Fusarium fujikuroi strain FGSC 8932	■																	▨		
Fusarium fujikuroi strain KSU 3368		■	▨			■														
Fusarium fujikuroi strain KSU X-10626			■																	
Fusarium subglutinans NSM 107	▨		■			▨			▨				■		▨					
Fusarium suuccisae	▨	▨	▨			■			▨			■	■		■			▨		
Fusarium thapsinum FRC M-6563		■	■		■	▨			▨				■	■				▨		
Fusarium udum	▨					■			▨				■		■			▨		
Fusarium verticillioides																				
Fusarium oxysporum f sp conglutinans race 2 54008	■	■	■	■		■			■			▨		■	■			■		
Fusarium oxysporum f sp cubense race 1	■	■	■	■		■							■					■		
Fusarium oxysporum f sp cubense race 4	■	■	■			■							■		▨			■		
Fusarium oxysporum f sp cubense tropical race 4 54006	■	■	■			■							▨		▨			■		
Fusarium oxysporum f sp lycopersici MN25	■	■	■	■									■	■	■			▨		
Fusarium oxysporum f sp radicis lycopersici 26381	■	■	■	■		■							■	▨	■			■		
Fusarium oxysporum f. sp. lycopersici 4287	■	▨	■	■		■							■	■	■			■		
Fusarium oxysporum f sp melonis 26406	■	■	■	■		▨			■				■	■	■			■		
Fusarium oxysporum f sp pisi hdv247	■		■	■		■							■	▨	■			■		
Fusarium oxysporum f sp raphani 54005	■	▨	■	■		■			■				■	▨	■			■		
Fusarium oxysporum f sp vasinfectum 25433	■	■	■	■		■			■			▨	■		■			■		
Fusarium oxysporum fo47	■		■	■		■							■	▨	■			■		
Fusarium oxysporum Fo5176	■	■	■	■		■			■			▨		▨	■			■		
Fusarium oxysporum FOSC 3-a	■	■	■	■		■								■	■			▨		
Fusarium oxysporum strain UASWS AC1	■	■	■	■		▨			■				■	▨	■			■		

	E Value
□	<1E-30
▨	<1E-100
■	0

3-ADON and 15-ADON during competition



Supplementary Fig. S1. Sample HPLC chromatographs that show abundance of 3-ADON and 15-ADON in FG1 and FG2 in axenic and co-inoculated cultures.