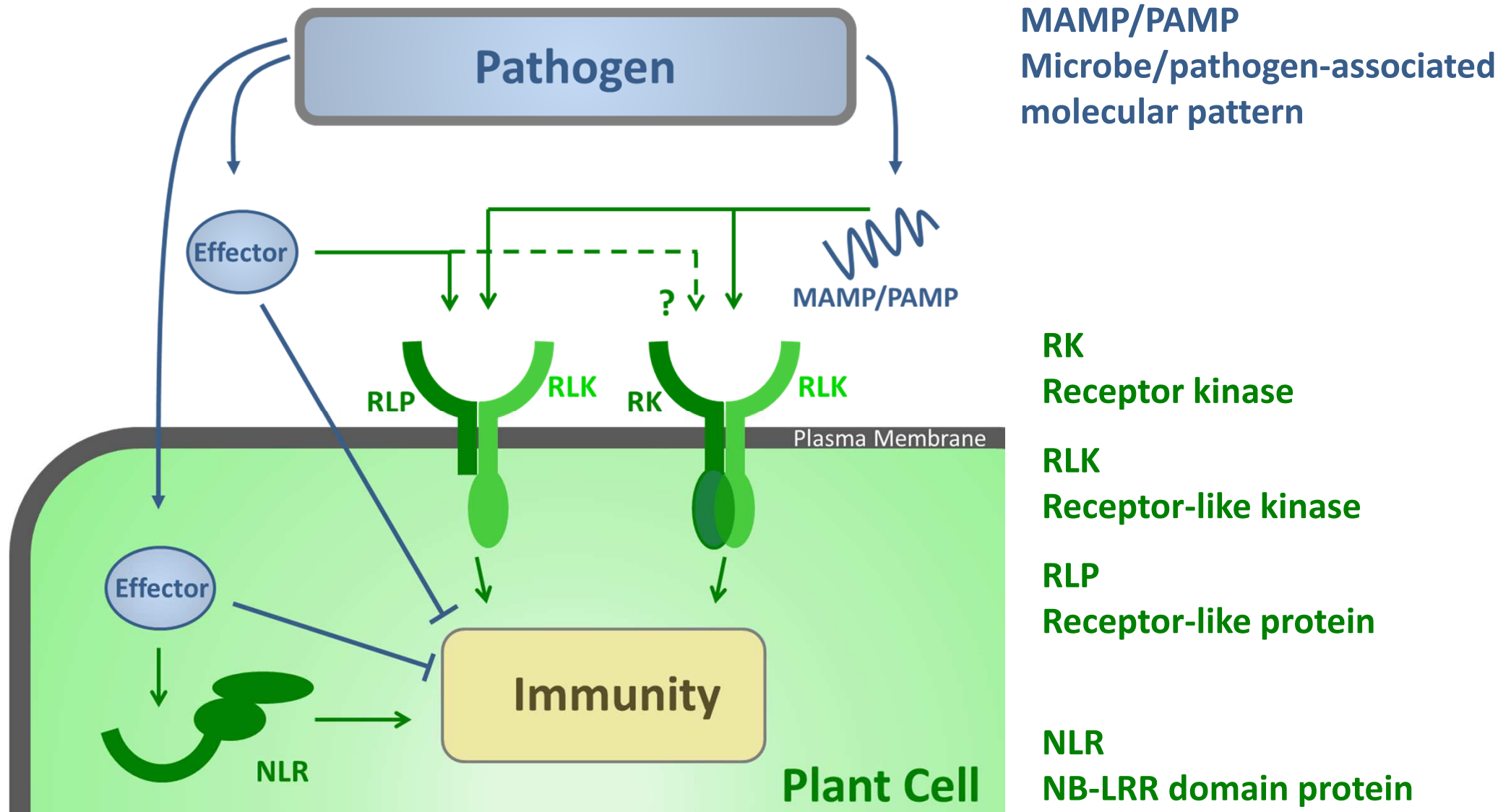


Plant NLR immune receptor complexes seem to act by an 'integrated decoy' mechanism

Thomas KROJ
BGPI, Montpellier

Plant Immunity

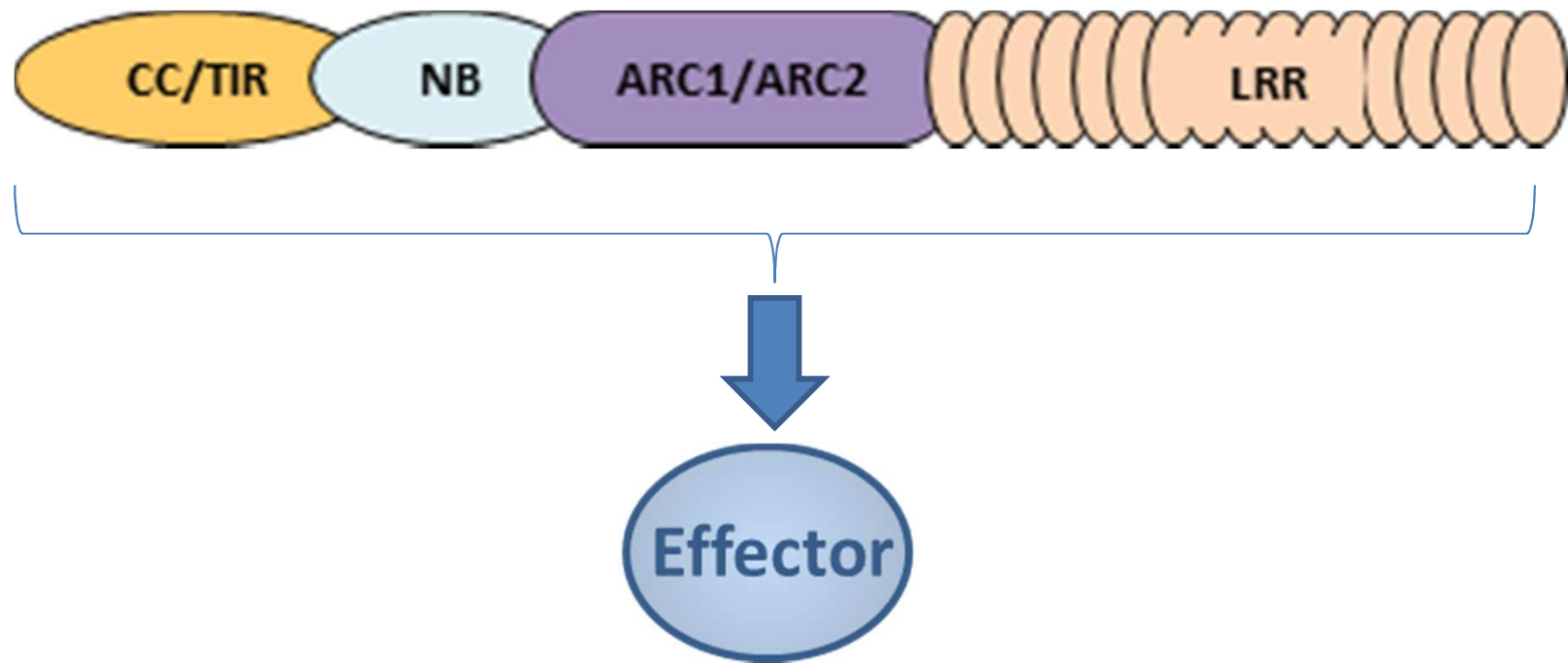


Plant NLR immune receptors

TIR Toll /Interleukin 1
CC Coiled-coil domain

NB Nucleotide-Binding
ARC APAF-2, R-protein, CED4

LRR Leucine-Rich Repeat

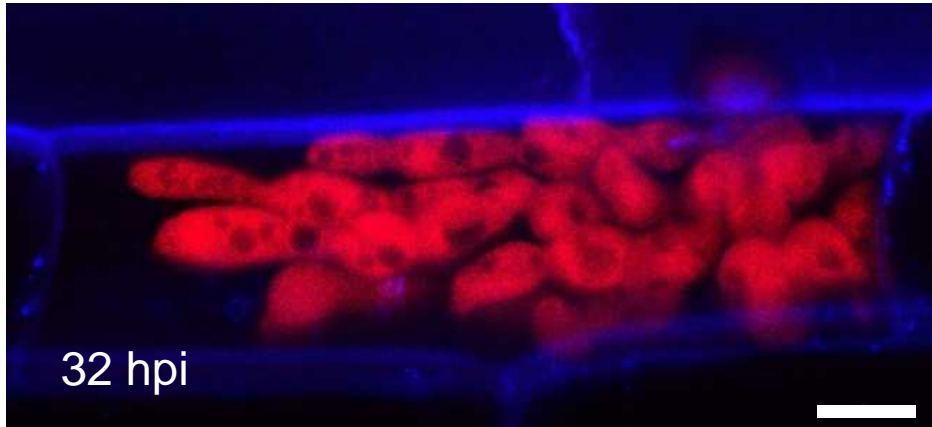


Specific, 'gene for gene' resistance

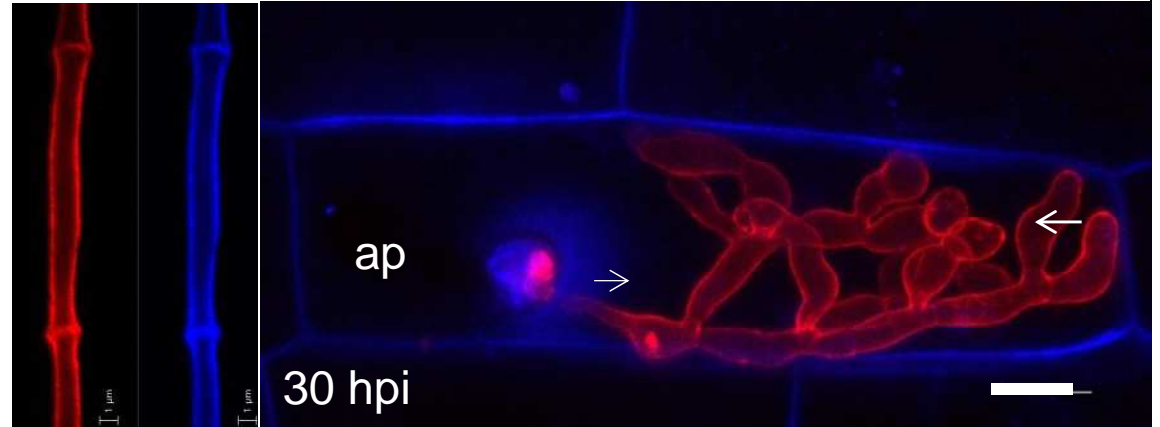
	<i>R</i>	<i>r</i>
<i>Avr</i>	Resistance (HR)	Disease
<i>avr</i>	Disease	Disease

AVR1-CO39 – a translocated effector!

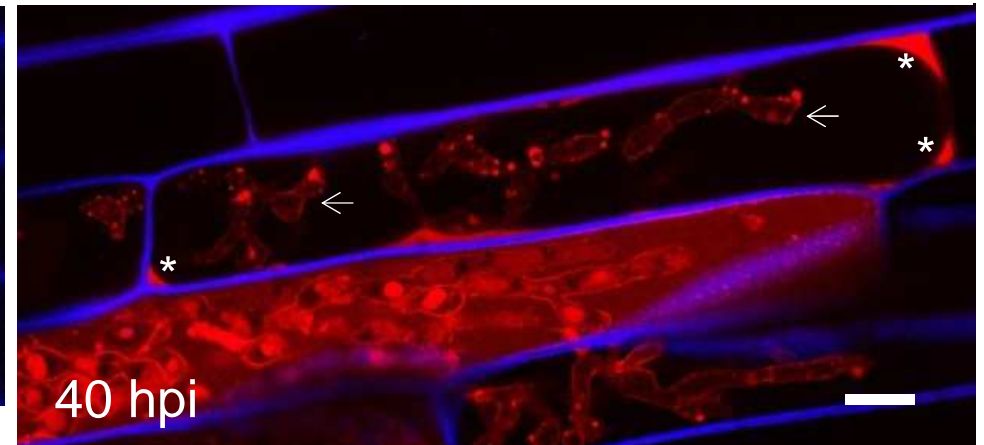
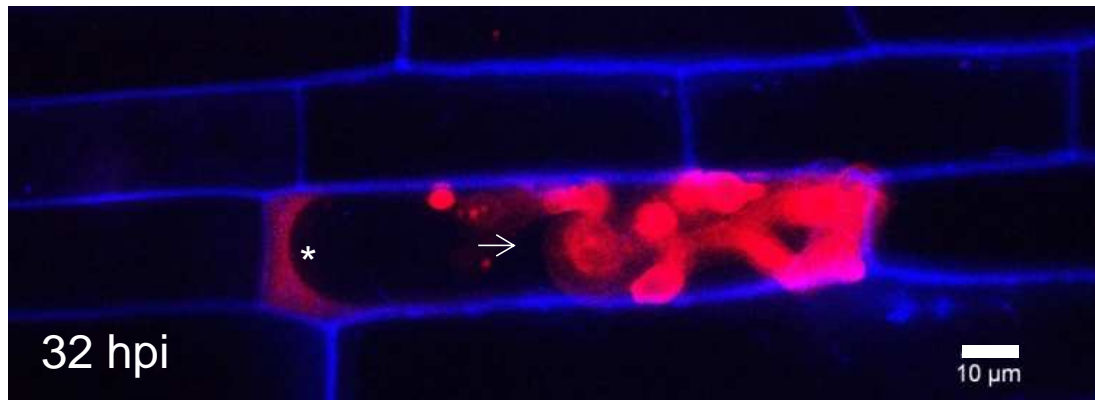
mRFP



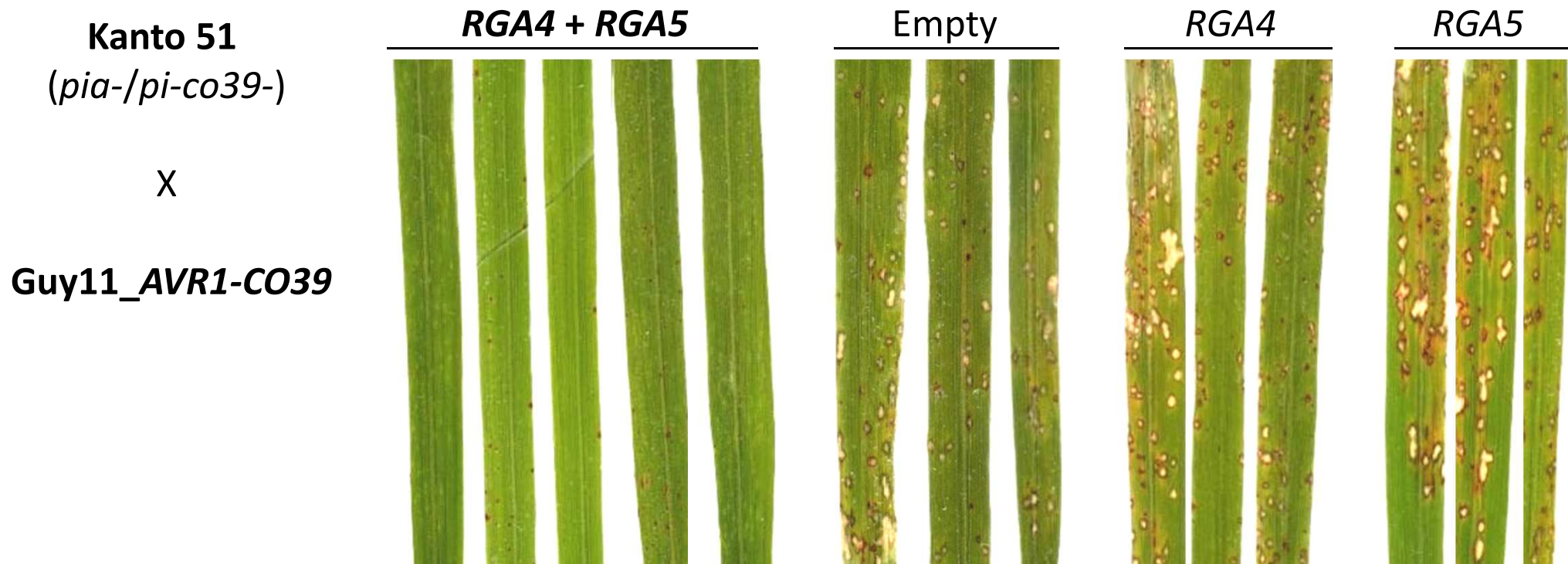
AVR1-CO39:mRFP



AVR1-CO39:mRFP



RGA4 and RGA5 confer resistance to AVR-Pia and AVR1-CO39

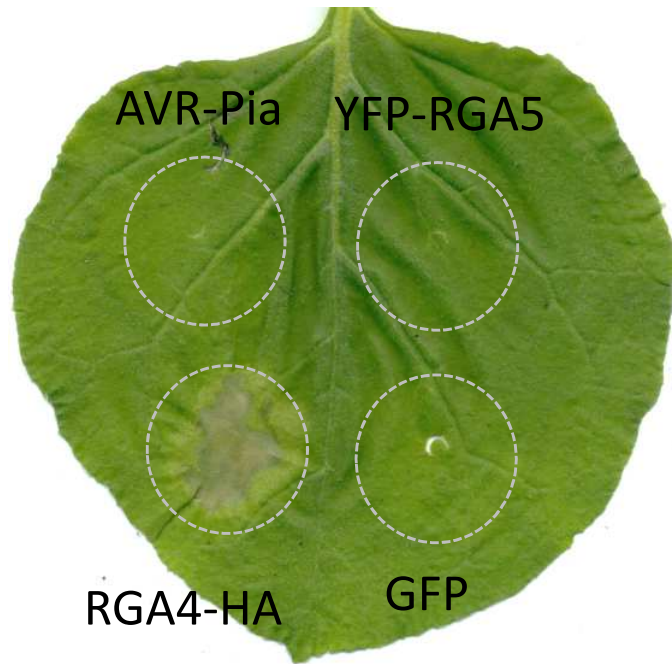


		rice			
		<i>RGA4</i> & <i>RGA5</i>	<i>rga4</i> & <i>rga5</i>	<i>RGA4</i> & <i>rga5</i>	<i>rga4</i> & <i>RGA5</i>
<i>M.oryzae</i>	-	disease	disease	disease	disease
	<i>AVR-Pia</i>	resistance (HR)	disease	disease	disease
	<i>AVR1-CO39</i>	resistance (HR)	disease	disease	disease

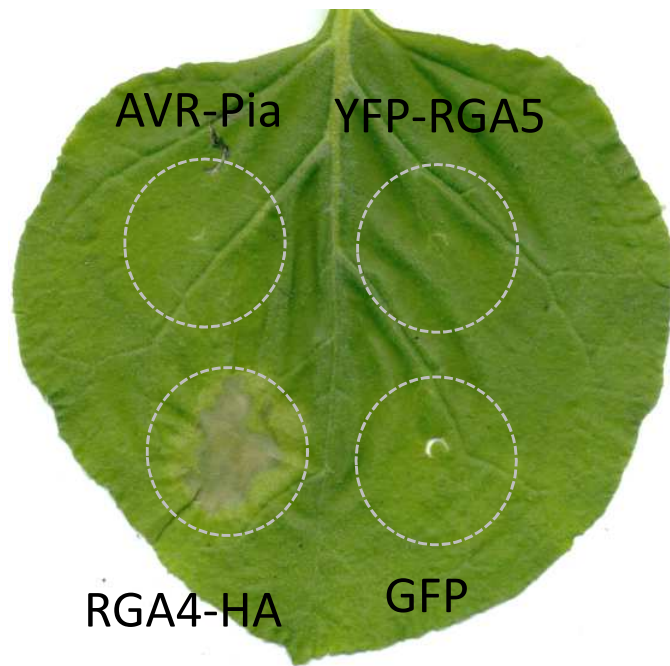
Pi-a Okuyama *et al.*, 2011, Plant Journal

Pi-CO39 Césari *et al.*, 2013, Plant Cell

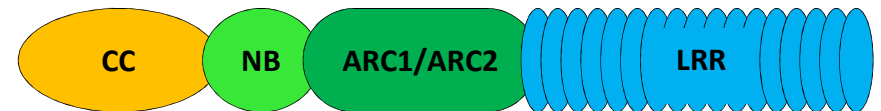
Investigation of RGA4 and RGA5 in *N. benthamiana* agroinfiltration assays



RGA4 auto activates HR-like cell death

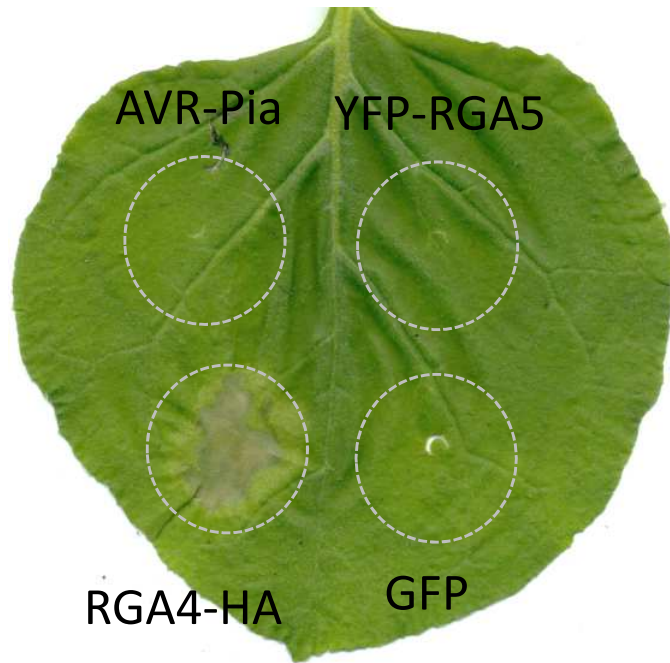


RGA4

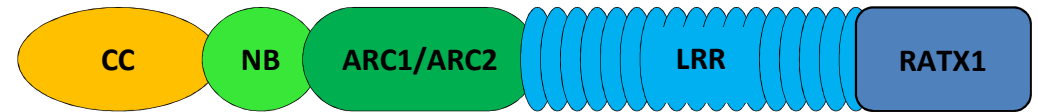


HR

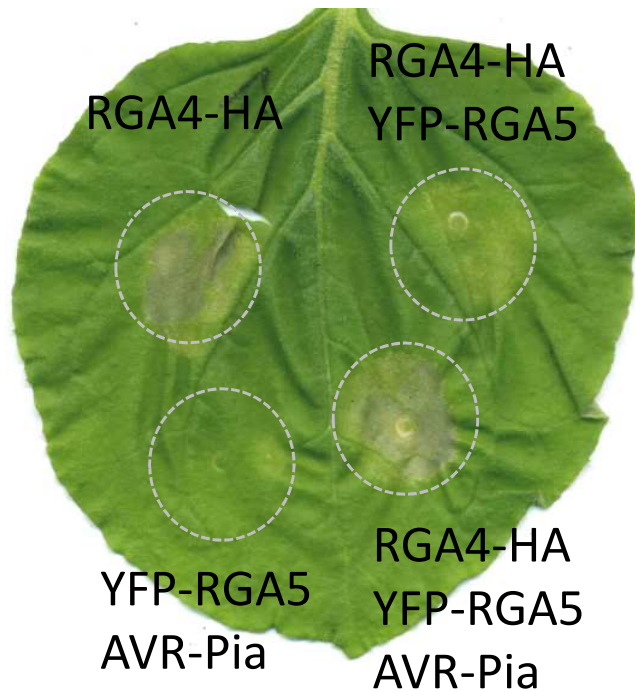
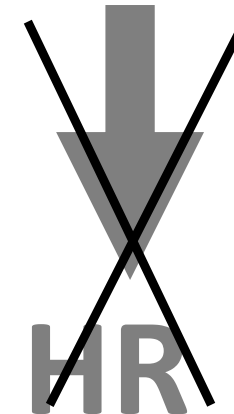
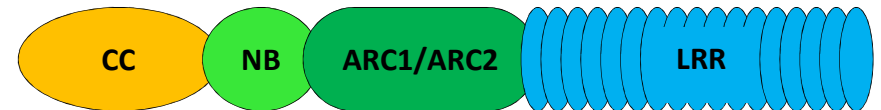
RGA4 auto activates HR-like cell death



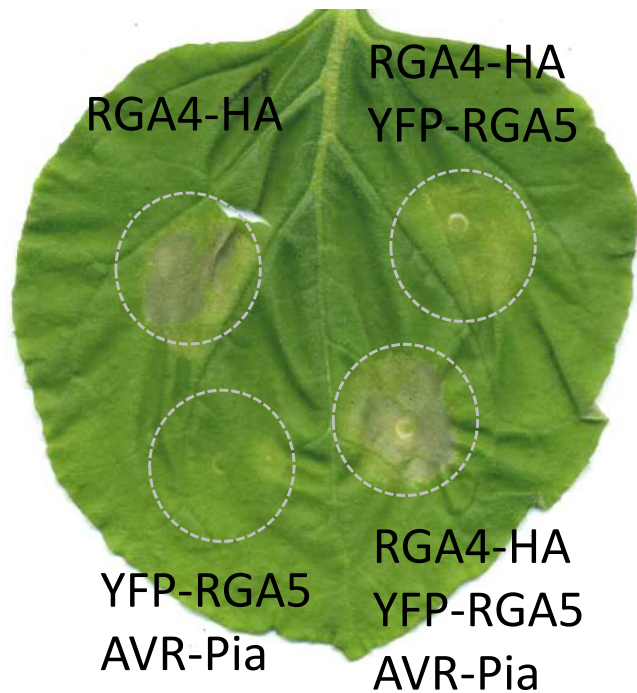
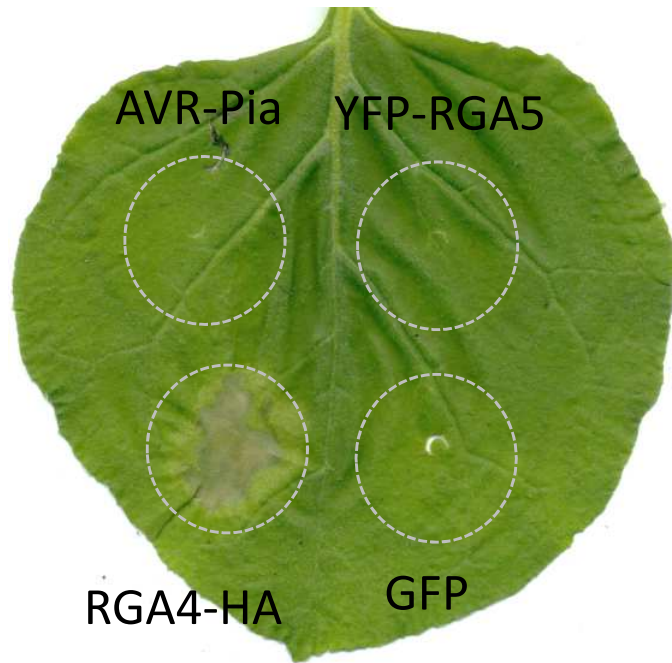
RGA5



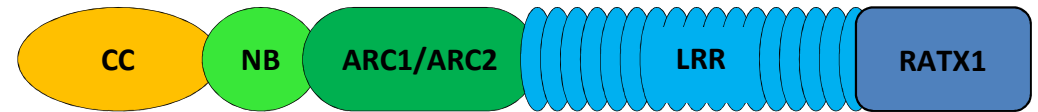
RGA4



RGA4 auto activates HR-like cell death



RGA5

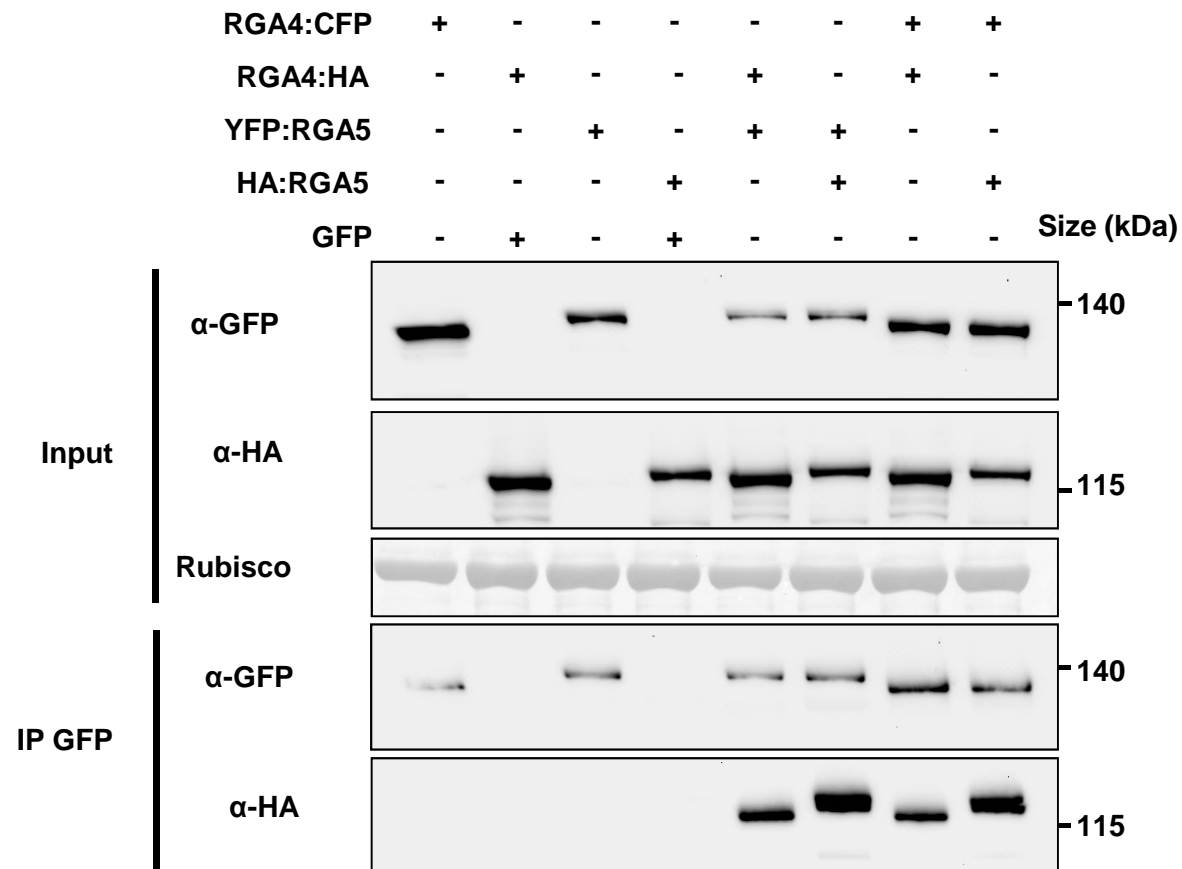


RGA4



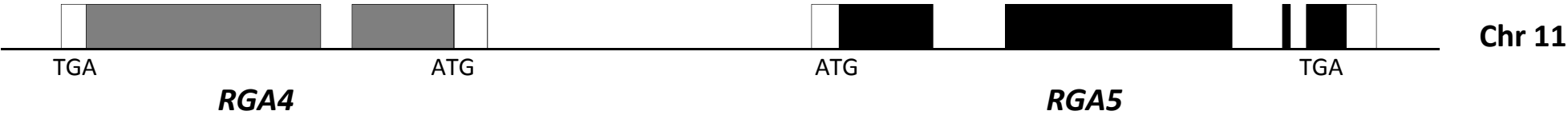
HR

RGA4 and RGA5 form homo and hetero-complexes



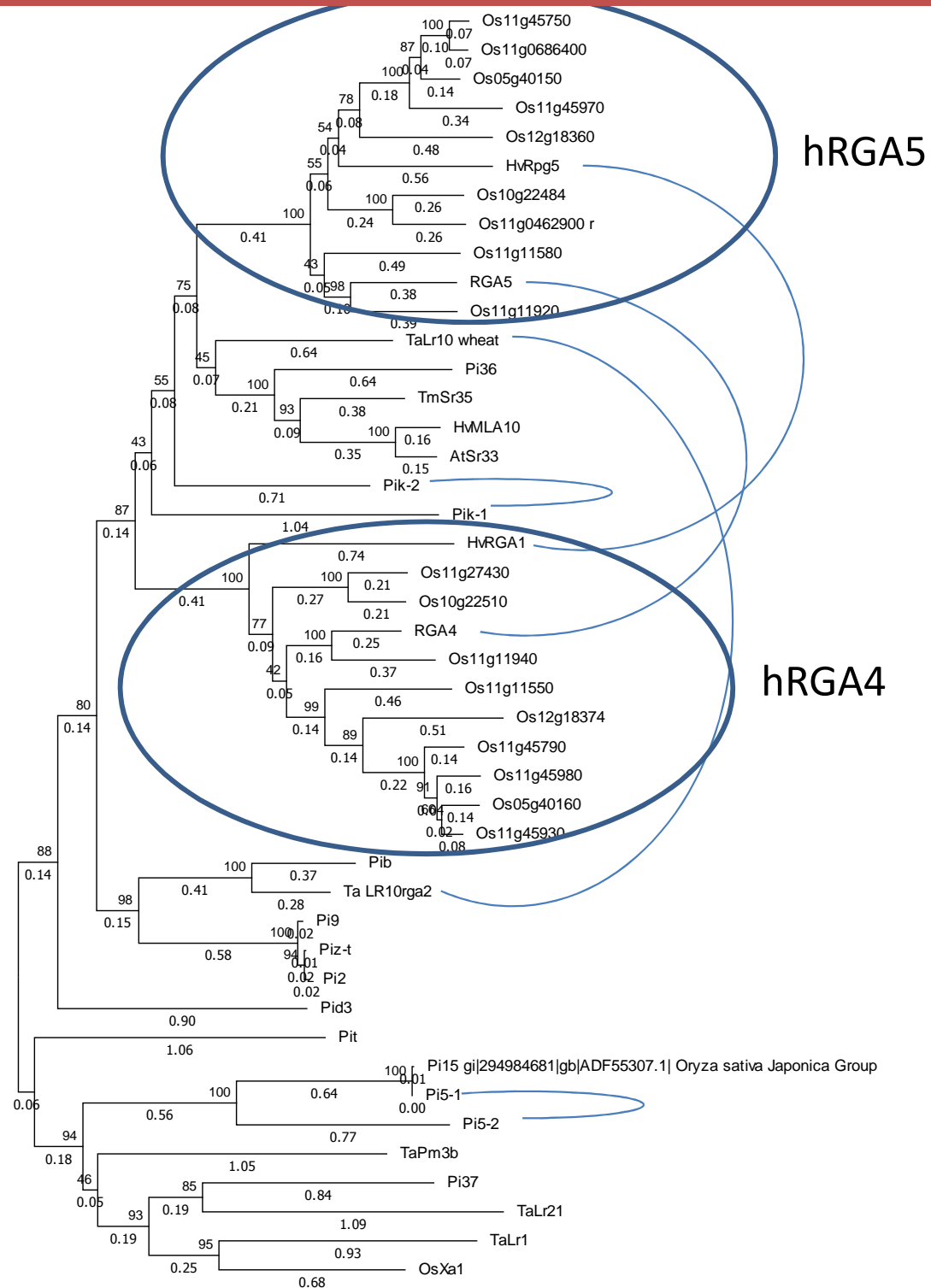
RGA4 and RGA5 confer resistance to AVR-Pia and AVR1-CO39

		rice			
		<i>RGA4</i> & <i>RGA5</i>	<i>rga4</i> & <i>rga5</i>	<i>RGA4</i> & <i>rga5</i>	<i>rga4</i> & <i>RGA5</i>
<i>M.oryzae</i>	-	disease	disease	disease	disease
	<i>AVR-Pia</i>	resistance (HR)	disease	disease	disease
	<i>AVR1-CO39</i>	resistance (HR)	disease	disease	disease

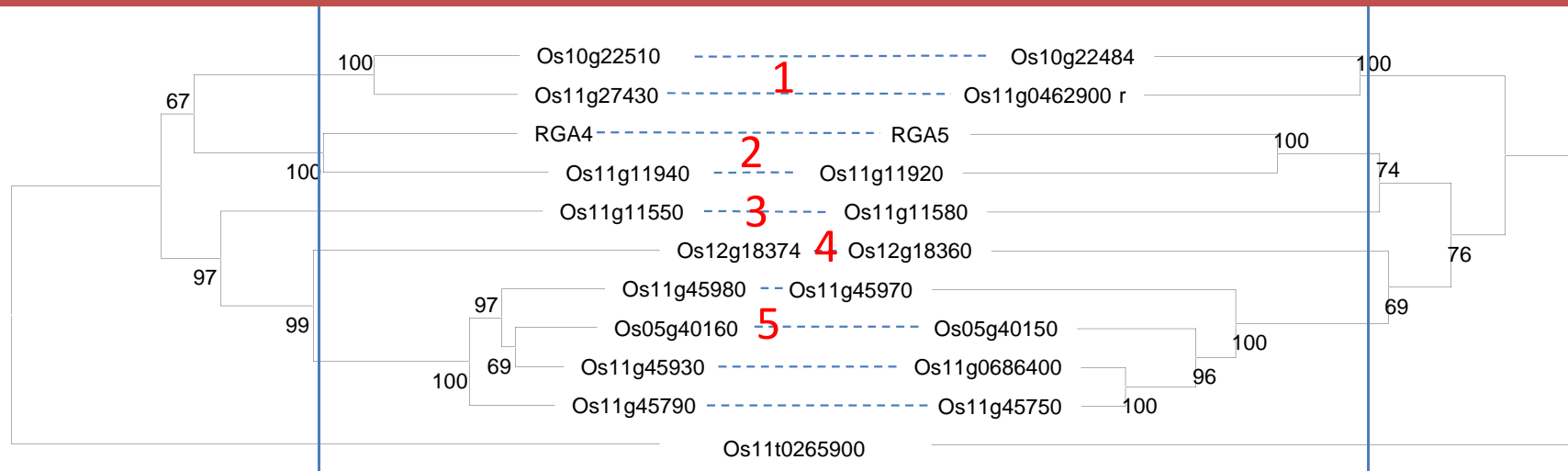


Rice	Pik-1/Pik-2 Pi5-1/Pi5-2	AVR-Pik
Arabidopsis	RRS1/RPS4 RPP2A/RPP2B	AvrRps4, PopP2
Wheat	LR10/RGA2	
Barley	RPG5/hvRga1	
Tobacco	N/NRG1	P50

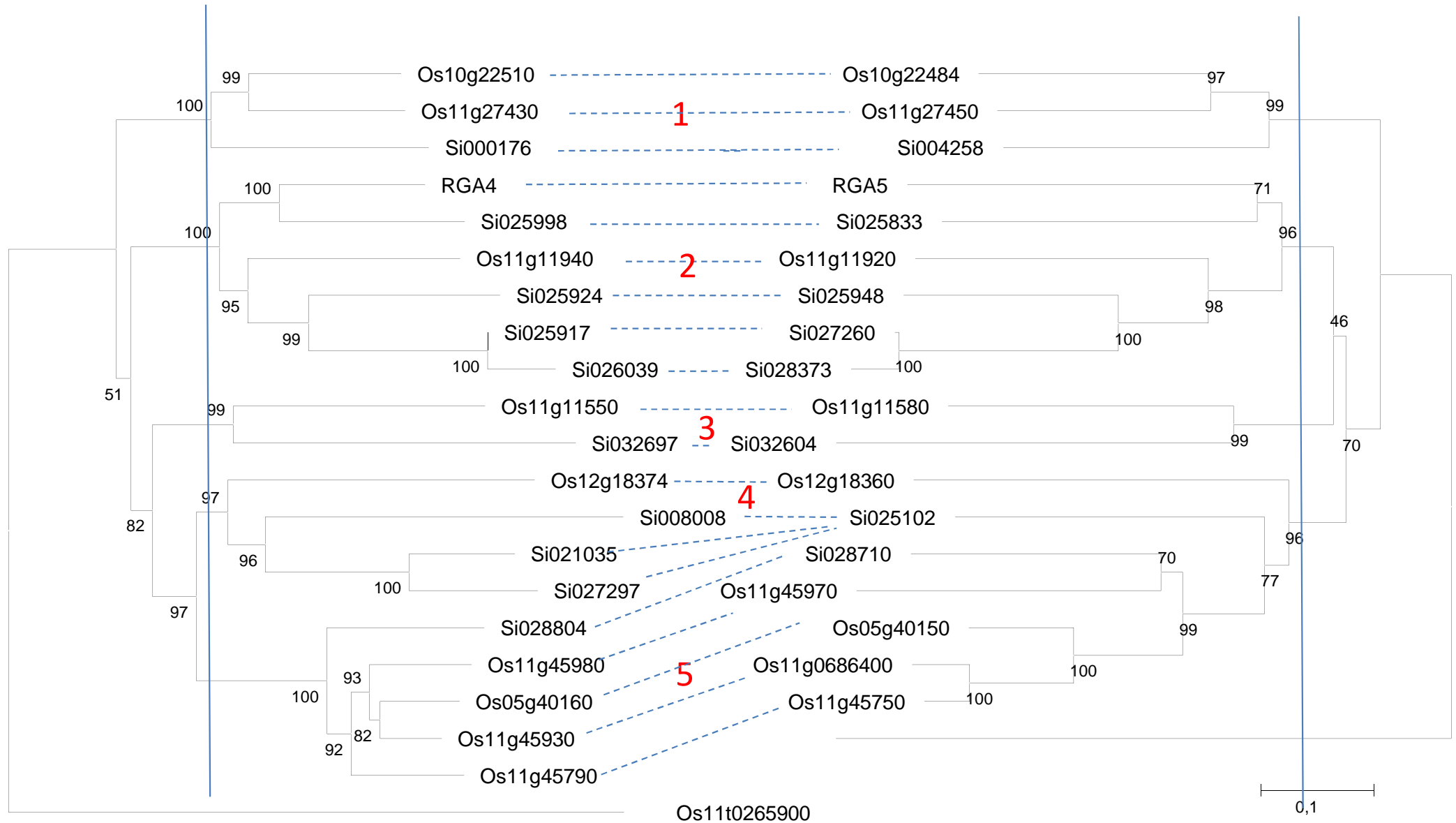
RGA and RGA5 homologs form distinct clades



hRA4s and hRGA5s show concordant phylogeny and form pairs



hRGA4/hRGA5 pairs are ancient and conserved in cereal genomes



hGRA4s and hRGA5s from *Setaria italica* (foxtail millet)

RGA4 and RGA5 are CC-NLRs

RGA4

CC

MEAALLSGFIKAILPRLFSLVDDKHKHLHKGVKGDIDFLIKELRMIVGAID
DDLSDLHPAAAAVQTLCDLRELAHGIEDCIDGVLYRAARDQQQSPVRR
AVQAPKKLQRNLQLAQQLQRLKRMAAEANQRKORYTAAAPGGHQGVYSSA
AAQVDEFPWPCSSASDPRIHEADLVG

NBS

VDADREELLEQLAERQPEQLKVIAIVGFCGLGKTALAAEAYNRETGGGRF
ERHAWVCAGHRSAREVLGELLRLRLDADGRSFHGSDAGQLCVDIRQLEK
NRYFIVIDDIQTEDQWKSISAFPTDKDIGSRIVVTTTIQSVANACCSAN
GYLHKMSRLDKNCCKQLLSKKAQPERYSHYKQPDAAAILKKCDGQPLALV
TIGEFQLANGWPTGPNCEDLCNRLHYHLENDKTLERMWRVLVRNYTSLPG
HALKACLLYFGMFPSDHPIRRKSLRLRWLAEGFVEPLSS

LRR

SSNIDSTAAFNVLMDRNIIEPINVSNNDKVKTCQT
YGMREFISHMSISQNFVTFCDKFVPKYVRRLSLHGDTVNGDNFNGI
DLSLVRSLAVFGEAGTTVLDFSKYQLLRVLDLEKDDLKDDHLKEICNLV
L
LKYLSLGGNISKLPKDIK
LKDLEALDVRRSKVKIMPVEVFG
LPCLIHLLGKFKLSKVKQKTEVQEFLKKGKSN
LQTLAGFASNGSEGFLHLMRYMNK
LRKLKIWCTSSAGSTDWTDLREAIQQFILDEKEANIGTRSLSLHFGSCSEDAINSLKEPCY
LSSLKLHGNFPQLPQFVTS
LRGLKELCLSSTKFTTGL
LEALSNLSYLQYLKLVADELEKFIIVQGFP
LLRLCIVLQYPTFPVIEEGA
LPFLVTLQLLCKDLHGLSDIQIECFKHLQEVTLH
SGVTPATRQEWVKAKEHPNRPKVLLKSVDTAESEHTDVSVMKSE
TTEYSIAPEGPEQVNNKMLDHGLESSSVLNKQNNFADQSSSKDLHYSP
NNMGLSDVSCCE

RGA5

CC

MDAPASFSLGAMGPLLRKLDSLLVAPEIRLPKPLKEGIELLKEDLEEIGV
SLVEHSVVDSPTHKARFWMDEVRLSYHIEDCIDTMFSMRSGDDGKPRS
ERRHKVGRAKIDGFSKKPKPCTRMARIAELRALVREASERLERYQLGDVC
GSSSPVVFTADGRARPLHHGVSANLVG

NBS

VDEFKTKLNRWLSDEEGPHLKVAAIVGPAGIGKTALATELYRDHRWQFEC
RAFVRASRKPMQRLGGLSQQVRRQRSSDAYADSTVQSLIDNLEHLQ
DRRYLIIIDGLWETAVERNANSAPFDVNSFSRILITADIEQVALECCGYK
YDYIMRMEPLGSLDSKKVFFNKVFGSEDQCPPELKEVSNTILEKCGGLPL
AIIISIAGLLSQPENPVLDYVTKYLCSSLGNTNPTLKDVKETLNLNSYN
LPHFPKTCLLYLGMYPDGHIMLKADLMKQWSAEGFVSANEA

LRR

KDTEEIVDKYFDELVNRGILEPVEINKNGKVLSCTLHHAVHDLVMPKFN
DKFTMSVDYSQTITGPSTMVRRSLHFSSTRYATKPAGIILSRVSLAFF
GLLNCMPICIGFKL
LRVLILEFWGSHGEQSRSLNLI PVR
LFQLRYLKTSGDVVVQLPAQISG
LQYLETLEIDARVSAVPFDLVH
LPNLLHLQLQDETCLPDGIGCMRS
LRTLQYFDLGNNSVDN
LRGLGELTNLQDLHLSYSAPSSNEGLMINLNAITSS
LSRLSNLKSILSPGAISMVIFFDISSIISVVPV
LQRELEPPICIFCRLPKSIQ
LHKLCILKVSVRELLTTDIDN
LTGLPSLTVLSLYAQTAPEGRFIFKDGT
LPVLKYFKFGCGELCLAFMAGAMPN
LQRLKLVFN
IRKSEKYRHTLFGIEHLVSLQDIATRIGVDTSTGESDRRAAESAFKETVN
KHPRCLRSSLQWVSTEEESHLEKQHHKREKSSAGHGVLEKESVEDSE
KNTDRVQTLSPQLSNMESVVESALTGQRTK

C-ter

IVVKVHMPGCKSRAKAMALAASVNGVDSVEITGEDKDRLVVVGRGIDPVR
LVALLREKCGLAELLMVELVE

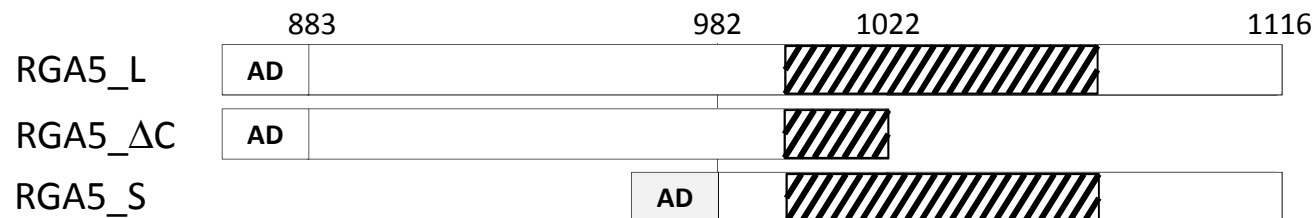
KEKTQLAGGKKGAYKKHPTYNLSPFDYVEYPPSAPIMQDINPCSTM

The C-terminus of RGA5 interacts physically with Avr effectors

RGA5	
CC	MDAPASFSLGAMGPLLRKLDLSLLVAPEIRLPKPLKEGIELLKEDLEEIGVSLVEHSV DSPTHKARFWMDEVRLSYHIEDCIDTMFSMRSGDDGKPRSERRHKVGRAKID GFSKKPKPCTRMARIAELRALVREASERLERYQLGDVCGSSSPVFTADGRARPLH HGVSANLVG
NBS	VDEFKTKLNRWLSDEEGPHLKVAIVGPAGIGKTALATELYRDHRWQFECRAFVR ASRKPDMMQRLGGILSQVRRQRSSDAYADSTVQSLIDNLRHLQDRRYLIIDGL WETAVWNIANSAFPDVSFSLITADIEQVALECCGYKYDYIMRMEPLGSLDSKK VFFNKVFGSEDQCPPELKEVSNILEKCGGLPLAISIAGLLGSQPENPVLWDYVTKY LCSSLGTNPTLKDVKETLNLNSYNSLPHPFKTCLLYLGMYPDGHIMLKADLMKQW SAEGFVSANEA
	KDTEEIVDKYFDELVNRGILEPVEINKNGKVLSTLHHAVHDLVMPKFNDKFTMS VDYSQITGPSTMVRRLSLHFSSTRYATKPAGIILSRVSLAFFGLNCPGIGEFKL
LRR	LRVLILEFWGSHGEQSRSLNIPVCR LFQLRYLKTSGDVVVQLPAQISG LQYLETLEIDARVSAVPFDLVH LPNLLHLQLQDETCLPDGIGCMRS LRTLQYFDLGNNVSDN LRGLGELTNLQDLHLSYAPSSNEGLMINLNAITSS LSRLSNLKSILSPGAISMVIFDISSIISVVPVF LQRELLPPICIFCRLPKISGQ LHKLCILKVSVRELLTDDIDN LTGLPSLTVLSLYAQTAPEGRFIFKDGT LPVLKYFKFGCGELCLAFMAGAMPN LQRLKLVFN
C-ter	IRKSEKYRHTLFGIEHLVSLQDIATRIGVDTSTGESDRRAESAFAKETVNHKPRCLRS SLQWVVSTEEESHLEKQHHKREKGSSAGHGVLKESVEDSEKNTDRVQTLSPQ <u>LSNMESVVESALTGQRTKIVVKVHMPCGKSRKAMALAASVNGVDSVEITGE</u> <u>DKDRLVVVGRGIDPVRLVALLREKCGLAELLMVELVEKEKTQLAGGKKGAYKKH</u> <u>PTYNLSPFDYVEYPPSAPIMQDINPCSTM*</u>

BD	AD	Mating control (DDO)	Selection (TDO)
AVR1-CO39	RGA5_L		
	RGA5_ΔC		
	RGA5_S		
AVR-Pia	RGA5_L		
	RGA5_ΔC		
	RGA5_S		

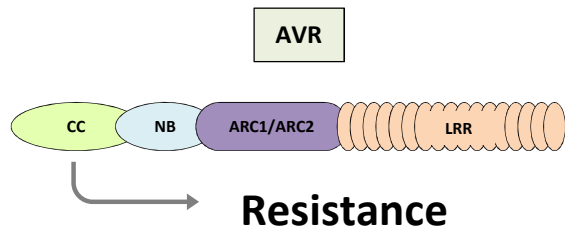
RATX1



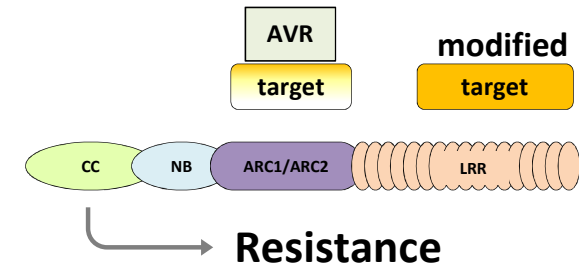
Césari *et al.* (2013), Plant Cell

Avr recognition by NLRs may be direct or indirect

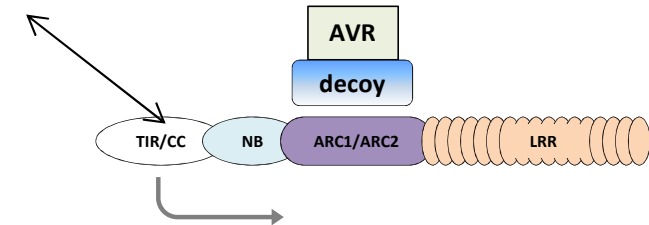
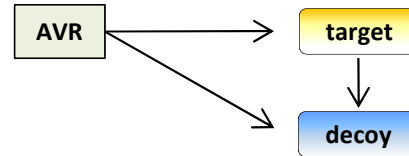
Direct recognition



Indirect recognition



Guard Model



Resistance Decoy model

Integrated Decoy model

