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Supplementary Materials

Receptor-like Kinases (LRR-RLKs) in Response of Plants to Biotic and Abiotic Stresses

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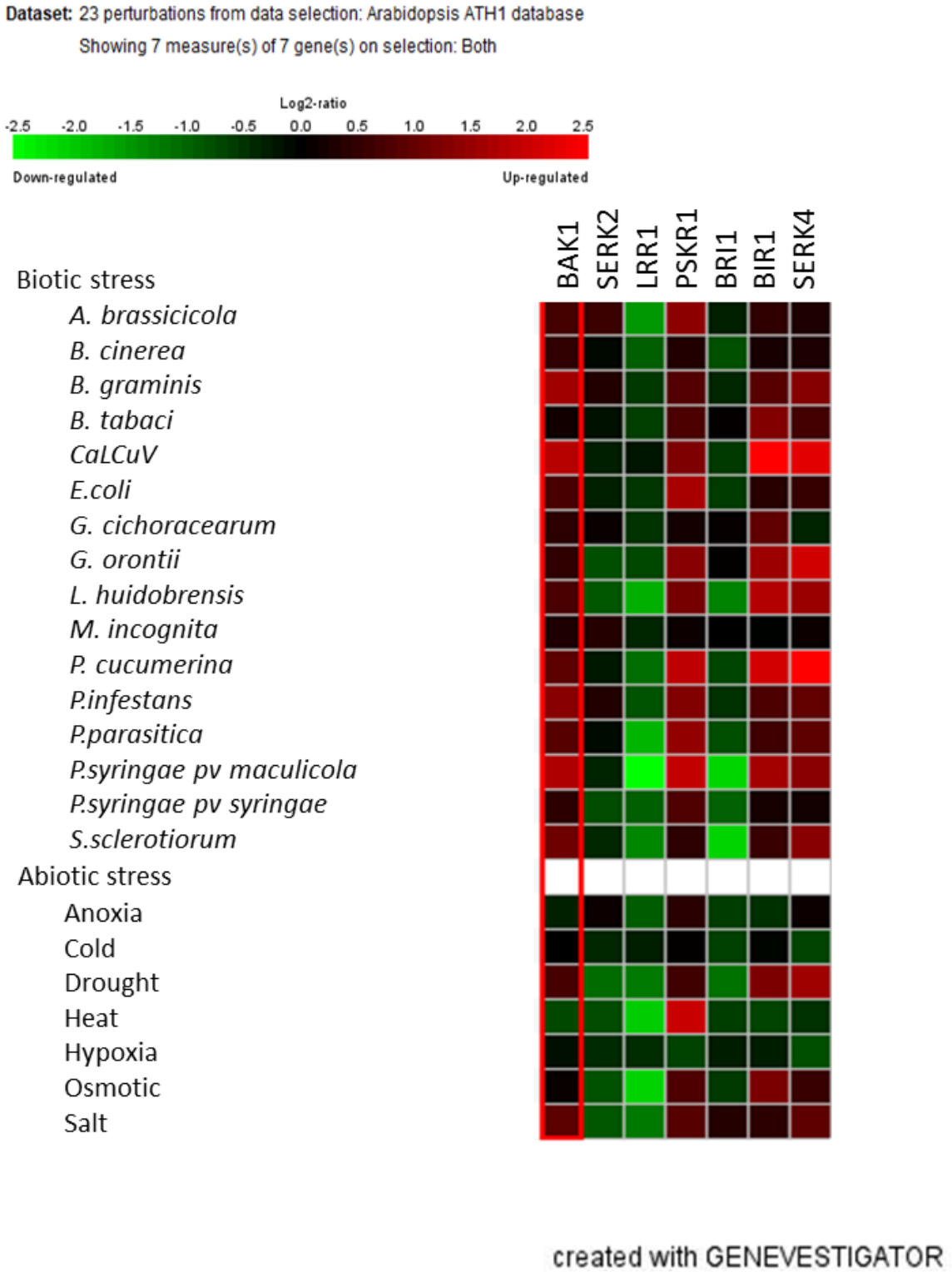
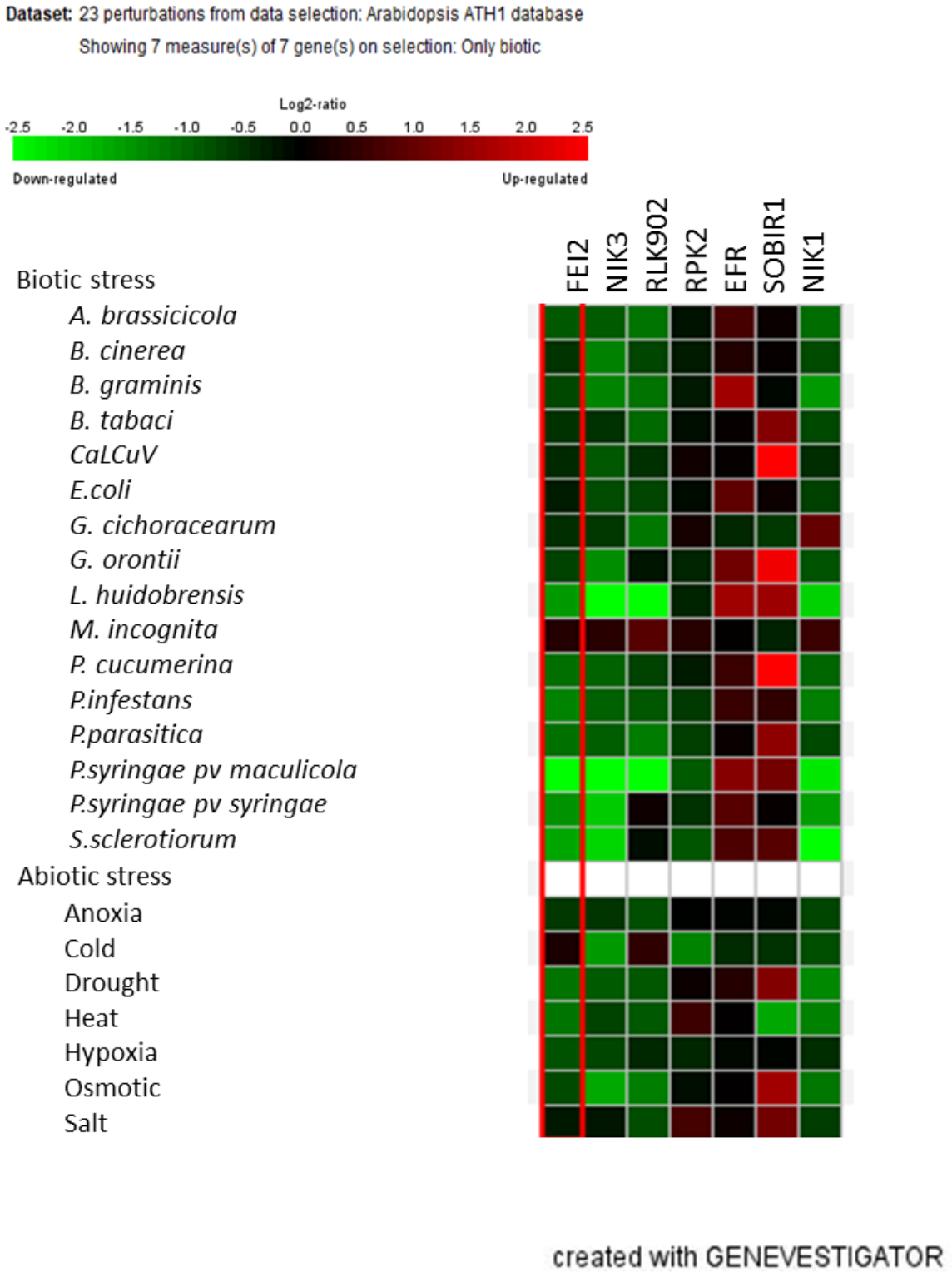
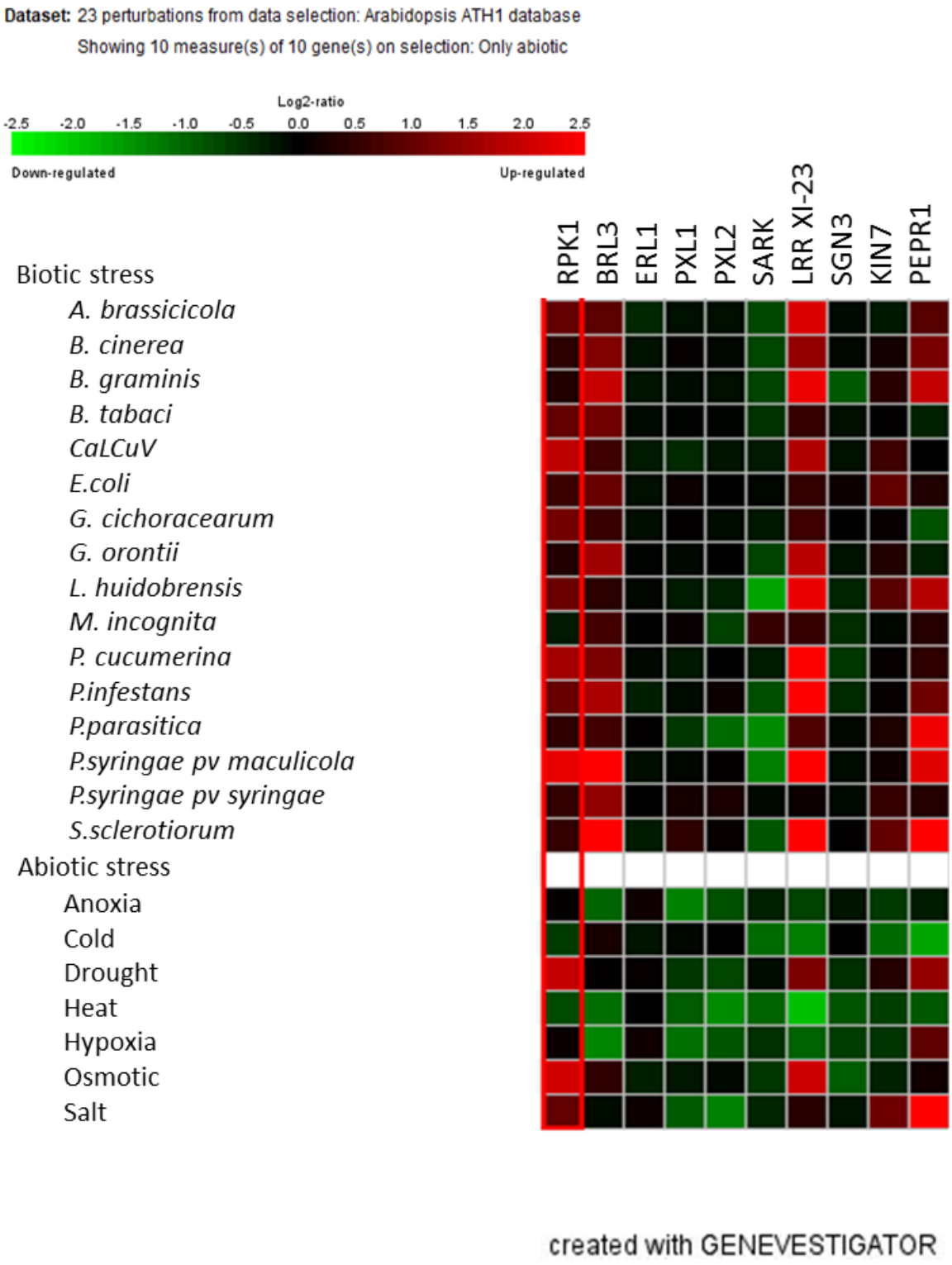


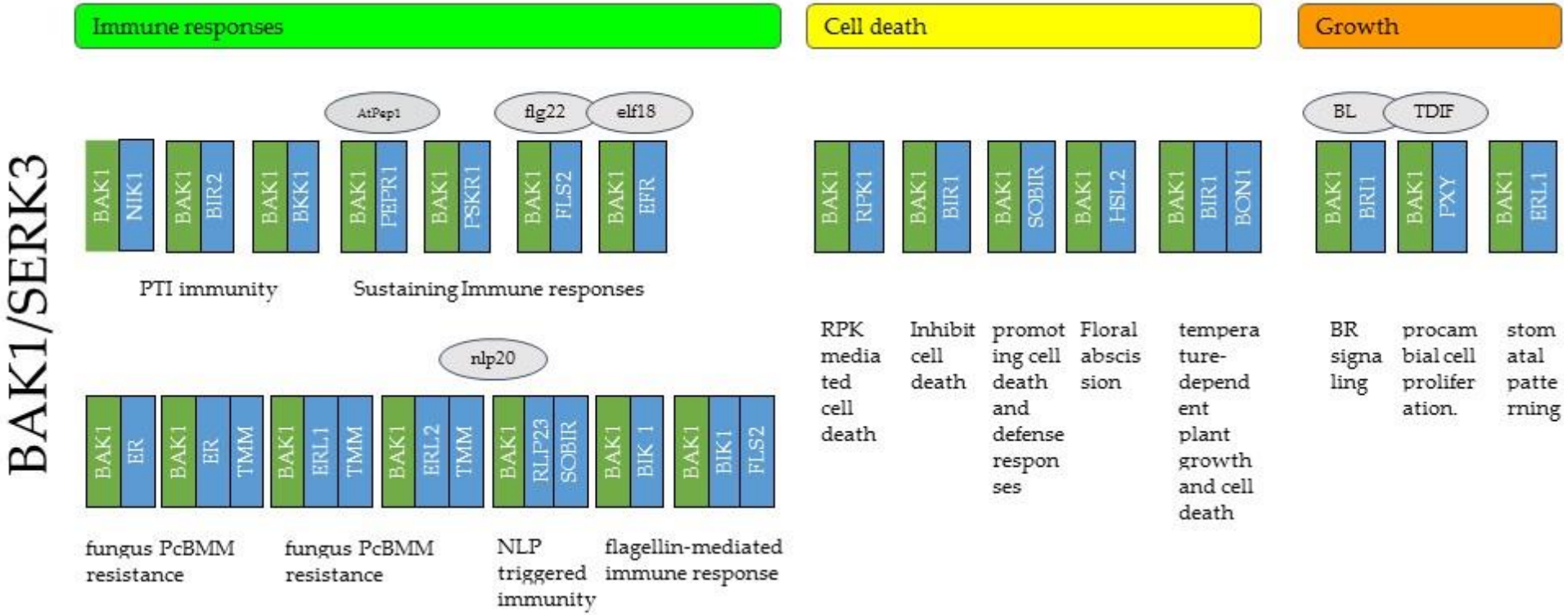
Supplementary Figure S1. Microarray analysis of the biotic and abiotic stress related LRR-RLK genes transcripts in response to biotic and abiotic stresses in WT (Col ecotype). Data was obtained from published microarray collections from Affymetrix *Arabidopsis* ATH1 Genome Array platform in Genevestigator (https://genevestigator.com/). Compendium-wide analysis was used to display the results by a condition search tool called perturbations. Data is displayed in the form of heatmap, which is based on Log2-ratio. Biotic and abiotic stress related LRR-RLK genes list from Supplemental table S1.



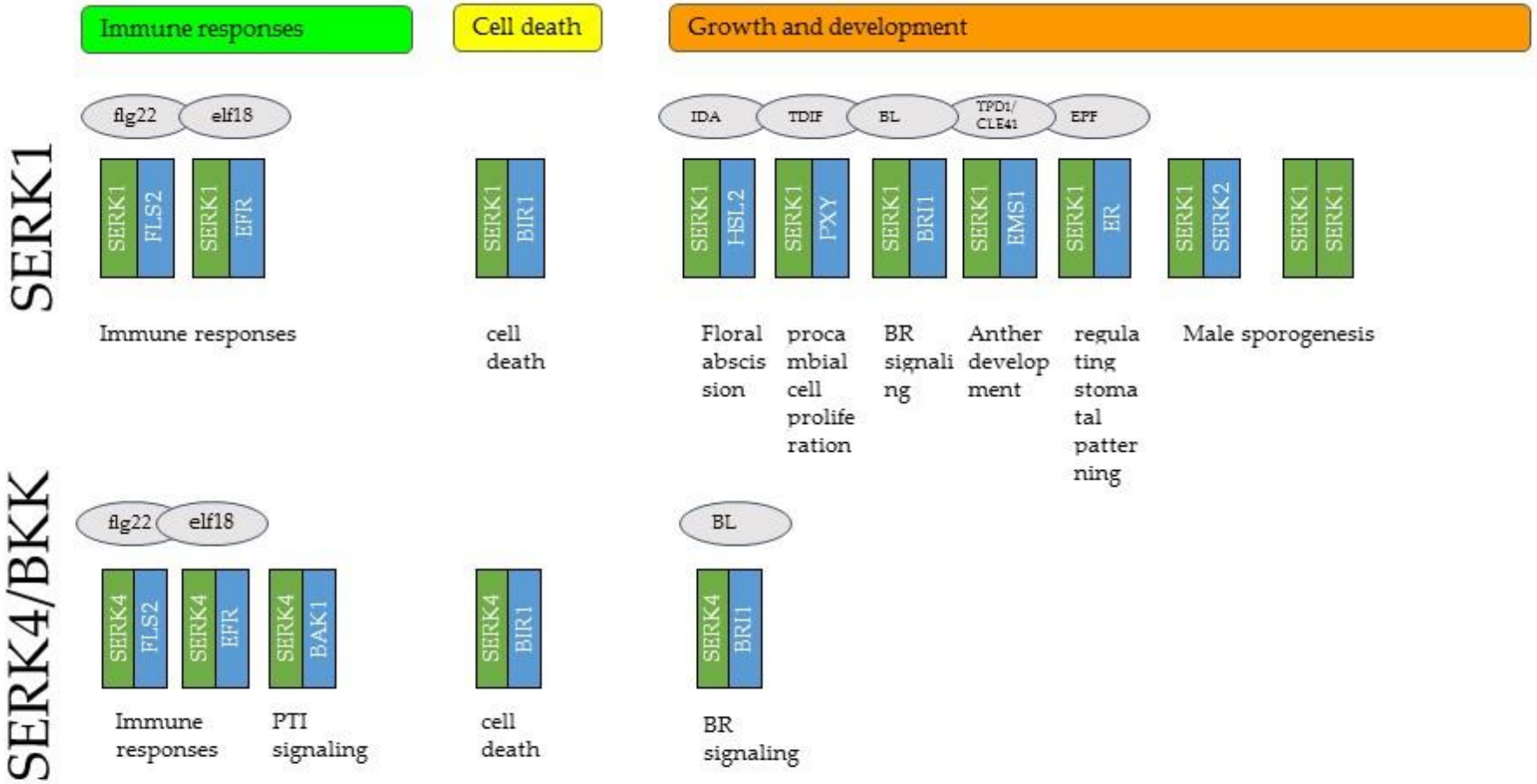
Supplementary Figure S2. Microarray analysis of the biotic stress related LRR-RLK genes transcripts in response to biotic and abiotic stresses in WT (Col ecotype). Data was obtained from published microarray collections from Affymetrix *Arabidopsis* ATH1 Genome Array platform in Genevestigator (https://genevestigator.com/). Compendium-wide analysis was used to display the results by a condition search tool called perturbations. Data is displayed in the form of heatmap, which is based on Log2-ratio. Biotic stress related LRR-RLK genes list from Supplemental table 1.



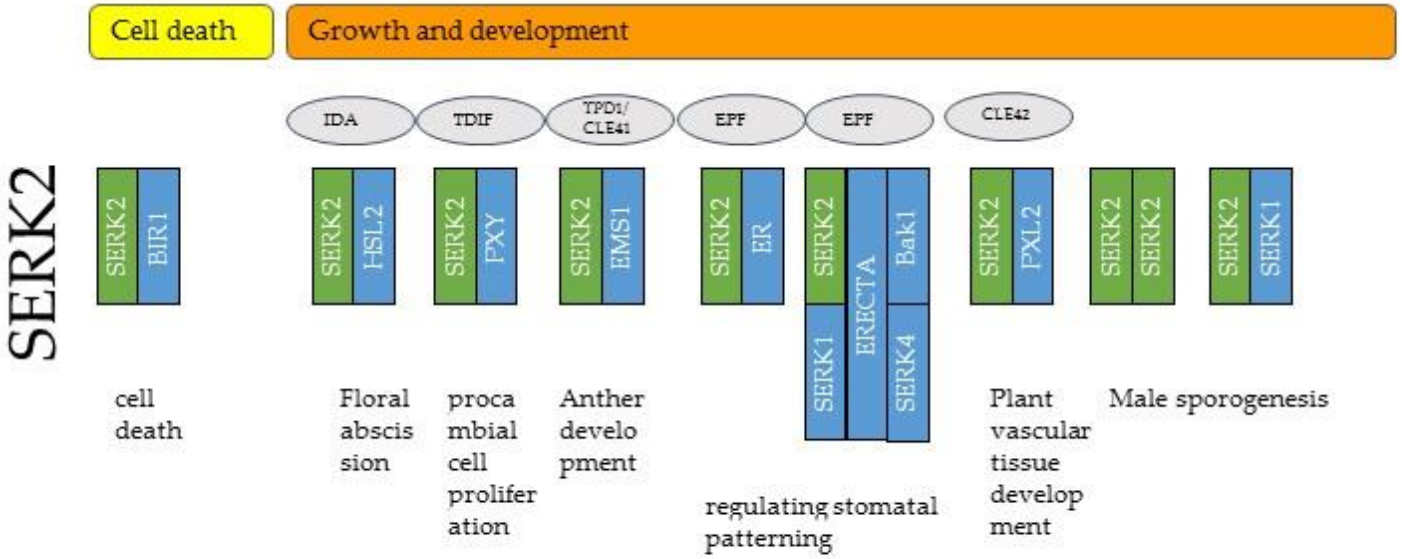
Supplementary Figure S3. Microarray analysis of the abiotic stress related LRR-RLK genes transcripts in response to biotic and abiotic stresses in WT (Col ecotype). Data was obtained from published microarray collections from Affymetrix *Arabidopsis* ATH1 Genome Array platform in Genevestigator (https://genevestigator.com/). Compendium-wide analysis was used to display the results by a condition search tool called perturbations. Data is displayed in the form of heatmap, which is based on Log2-ratio. Abiotic stress related LRR-RLK genes list from Supplemental table 1.



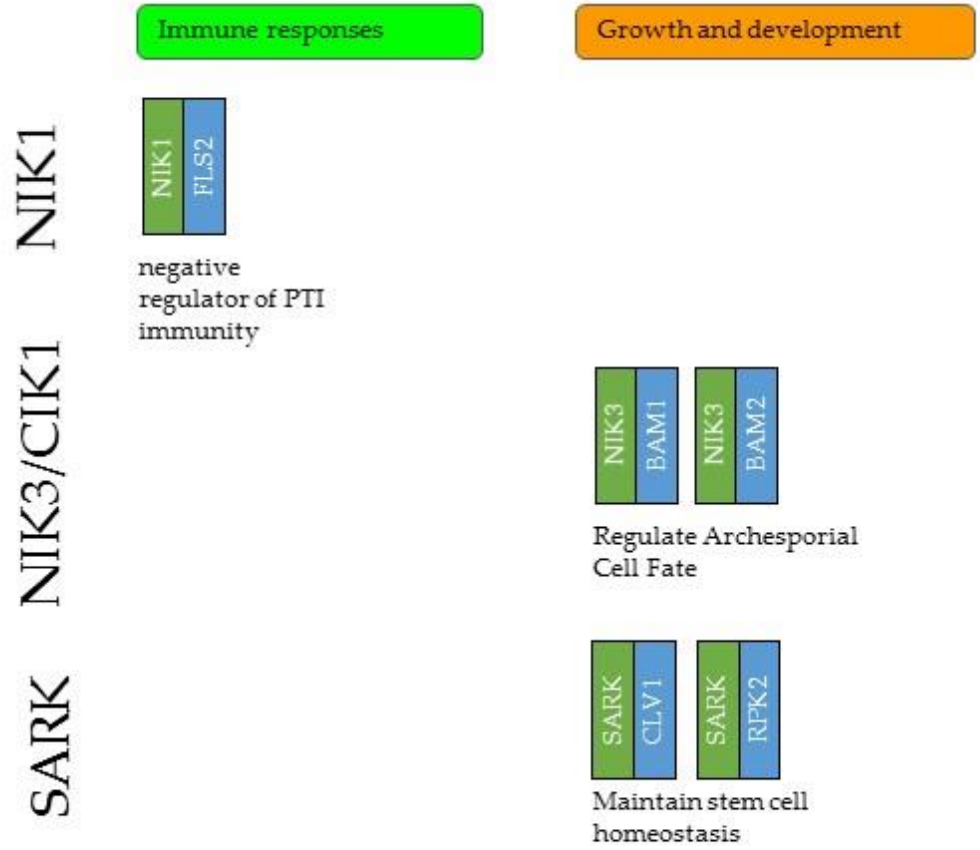
Supplementary Figure S4. Protein interactions of BAK1/**SERK3** with other LRR-RLK with experimental proved functional role.



Supplementary Figure S5. Protein interactions of **SERK1 and SERK4** with other LRR-RLK with experimental proved functional role.



Supplementary Figure S6. Protein interactions of **SERK2** with other LRR-RLK with experimental proved functional role.



Supplementary Figure S7. Protein interactions of **CIK's (NIK1, NIK3 and SARK)** with other LRR-RLK with experimental proved functional role.

Table S1. Phenotypes of single mutants of LRR-RLK genes in *A.thaliana* tested under different biotic and abiotic stresses. The LRR-RLK genes names and their numbers were given. All data taken from different research studies about LRR-RLK genes investigating them under biotic (organism/s and/or component of tested organism) and abiotic (ABA, salt, temperature changes, dark, light intensity, drought, oxidative stress) stimuli and also appearance of senescence symptoms. OE indicates overexpression, NA indicates-not available, WT- wild type.

GENES	ATG numbers	USED MUTANTS	BIOTIC STRESS	ABIOTIC STRESS	reference
BAK1	AT4G33430	*bak1-5; bak1-3, bak1-4*	sensitive to *A.brassicicola*	insensitive to ABA	[73,74,160]
			sensitive to *P.syringae*		
		OEBAK1	NA	NA	
SERK2	AT1G34210	*serk2*	sensitive to *S.sclerotiorum*	sensitive to salt	[79,80]
				sensitive to ABA	[80]
		OESERK2	NA	tolerant to salt	[80]
SERK4	AT2G13790	*serk4; serk4-1*	weakly sensitive to BR treatment	early senescence	[20,81,161]
			sensitive to flg22 treatment		
		OESERK4	NA	delay senescence	[81]
BRI1	AT4G39400	*bri1; bri1-5*	disease resistant	sensitive to cold	
				sensitive to ABA	[74]
				sensitive to dark, light	[162]
		OEBRI	NA	sensitive to ABA on seed germination stage	[162]
BIR1	AT5G48380	*bir1-1*	resistant to biotrophic oomycete	sensitive to temperature change	[72,163]
		OEBIR1	NA	NA	
EFR	AT5G20480	*efr*	sensitive to *Agrobacterium*	NA	[98]
		OEEFR	NA	NA	
SOBIR1	AT2G31880	*sobir1*	insensitive to nlp20 treatment	NA	[13]
			sensitive to *S.sclerotiorum* and *B.cinerea*		
		OESOBIR1	NA	NA	
PSKR1	AT2G02220	*pskr1; pskr1-3*	sensitive to *A.brassicicola*	early senescence	[104]
			resistant to *P.syringae*		[164]
			sensitive to fungal elicitor E-Fol		[165]
		OEPSKR1	NA	delay senescence	[104]
PEPR1	AT1G73080	*pepr1*	NA	sensitive to salt stress	[106]

				insensitive to *At*Pep1-induced stomatal closure	[107]
		OEPEPR1	NA	NA	
LRR1	AT5G16590	*lrr1*	NA	sensitive to drought	[111]
		OELRR1	resistant to *P.syringae*	NA	[110]
			resistant to *Hyaloperonospora*		[110]
KIN7	AT3G02880	*kin7*	NA	sensitive to drought	[111]
				insensitive to increased CO2 level	[112]
		OEKIN7	NA	NA	
RLK902	AT3G17840	*rlk902*	sensitive to *P.syringae*	NA	[116]
			resistant to downy mildew		[115]
		OERLK902	resistant to *P.syringae*	NA	[116]
NIK1	AT5G16000	*nik1*	sensitive to geminivirus	NA	[166]
		OENIK1	resistant to kanamycin	NA	[167]
NIK3	AT1G60800	*nik3*	sensitive to geminivirus	NA	[117]
			sensitive to CaLCuV infection		[117]
		OENIK3	NA	NA	
FEI2	AT2G35620	*fei2*	sensitive to *B.cinerea*	NA	[118]
		OEFEI2	NA	NA	
RPK2	AT3G02130	*rpk2*	sensitive to nematode infection	NA	[128]
		OERPK2	NA	NA	
ERL1	AT5G62230	*erl1*	NA	sensitive to salt	[120]
		OEERL1	NA	NA	
PXL1	AT1G08590	*pxl1*	NA	sensitive to cold and heat	[122]
		OEPXL1	NA	insensitive to heat	[122]
PXL2	AT4G28650	*pxl2*	NA	sensitive to ABA	[121]
		OEPXL2	NA	NA	
LRR XI-23/ RLK7	AT1G09970	*lrr/rlk7*	NA	tolerant to H2O2 treatment	[127]
		OELRK7	NA	intolerant to H2O2 treatment	[127]

RPK1	AT1G69270	*rpk1*	NA	insensitive to ABA	[168]
		OERPK1	NA	tolerant to drought, oxidative stress	[169]
BRL3	AT3G13380	*brl3*	NA	sensitive to high glucose	[124]
		OEBRL3	NA	tolerant to drought	[125]
SARK	AT4G30520	*sark-1*	NA	delay leaf senescence	[130]
		OESARK	NA	early senescence	[130]
SGN3	AT4G20140	*sgn3*	NA	hypersensitive to low potassium	[123]
		OESGN3	NA	NA	

Table S2. Orthologous of stress related LRR-RLKs genes in *A.thaliana, O.sativa, G.max, M.truncatula, Populus*, *V. vinifera*, *S.lycopersicum*, *B.napus*, *Z.mays*. Orthologous of LRR-RLKs genes tested for different stress stimuli were taken from ATTED database (https://atted.jp/). The respective sequence of shown locuses for different plant species are in ATTED database.

Genes	*Plants*								
	A.thaliana	*O.sativa*	*G.max*	*M.truncatula*	*Populus*	*V.vinifera*	*S.lycopersicum*	*B.napus*	*Z.mays*
RKL1	RLK902	LOC4332106 LOC4333893	LOC100781597 LOC100788892 LOC100801582 LOC100818955	LOC11408124 LOC11435862 LOC25497283	LOC7474836 LOC7487396	LOC100243943 LOC100267283	LOC101247929 LOC101254257 LOC101268851	LOC103833000 LOC103838993 LOC103869641	LOC542104 LOC100285260 LOC100285980
PEPR2	PEPR1	LOC4345707 LOC4345708	LOC100778035 LOC100781454 LOC100802056 LOC100817655	LOC11415181 LOC25488017	LOC7486765 LOC7497791	LOC100258774	PORK1	LOC103830768 LOC103872555 LOC103872556	LOC100381406 LOC103643254
IRK	AT5G01890	LOC4327614 LOC4332757 LOC4339111	LOC100780307 LOC100791204 LOC100791629 LOC100813535	LOC11433630 LOC25489825	LOC7459241 LOC7482595 LOC7497359	LOC100248331 LOC100257029	LOC101247434 LOC101254001 LOC101262241	LOC103841545 LOC103850399	LOC100274594 LOC100304322 LOC103630489
FEI2	FEI1	LOC4332359	LOC100816028 LOC100819230	LOC11410978		LOC100264793	LOC101257290	LOC103857572 LOC103865464 LOC103867340	LOC100280440 LOC100281527
LRR XI-23/ RLK7	IKU2	LOC4352872	LOC100779554 LOC100809356 LOC100811489	LOC11418845 LOC25490156	LOC7469669	LOC100248069 LOC109121676	LOC101243702 LOC101255038	LOC103837012 LOC103843324 LOC103868127 LOC103871776	LOC103650295
PXY		LOC4344655	LOC100809695 LOC100813189	LOC25491892	LOC7465499	LOC100266344	LOC101256593 LOC101263386	LOC103860599	LOC100383417
PXL1	AT4G28650	LOC4328049 LOC4331599	LOC100779939 LOC100788430 LOC100789665 LOC100793873 LOC100811284 LOC100817339	LOC11411044 LOC11421682 LOC25484201	LOC7461486 LOC7487195 LOC7487717	LOC109122934	LOC101246467 LOC101249348	LOC103836383 LOC103854284	LOC103626517 LOC103631713 LOC103639559
PXL2	AT1G08590	LOC4328049 LOC4331599	LOC100779939 LOC100788430 LOC100789665 LOC100793873 LOC100811284 LOC100817339	LOC11411044 LOC11421682 LOC25484201	LOC7461486 LOC7487195 LOC7487717	LOC109122934	LOC101246467 LOC101249348	LOC103836383 LOC103854284	LOC103626517 LOC103631713 LOC103639559

BAM1	BAM2	LOC4332141	RLK1	LOC11408427	LOC7465379	LOC100258232	LOC101248733	LOC103834155	
	BAM3	LOC4334273	RLK3	LOC11424811	LOC7465545	LOC100855393	LOC101248913	LOC103858059	LOC103644083
		LOC4342345	RLK2	LOC11431479			LOC101264597	LOC103860625	LOC100279272
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			LOC100777902					LOC103874010	LOC109939609
			LOC100803075						
			LOC100815103						
			LOC100816158						
SERK1	SERK4	LOC4336035	LOC100305355	LOC11421599	LOC7478140	LOC100247340	SERK3A	LOC103830829	LOC542015
	SERK5	LOC4344785	SERK1	LOC11428529		LOC100247683	SERK1	LRRII6	LOC542016
	BAK1		LOC100789884	LOC11430748		LOC100253855	SERK3B	LOC103834483	LOC542670
	SERK2		LOC100800522	LOC25485006		LOC100266543		LRRII5	LOC103641205
			LOC100813918					LRRII4	
								LOC103862237	
CLV1		LOC4342080	NARK	LOC11438702	LOC7490636	LOC100260741	CLV1	LOC103832028	LOC103626458
			CLV1A	LOC11439632					
			LOC102664073						
CRN		LOC4326956	LOC102664172	LOC11437782	LOC7491429	LOC104880871	LOC101055499	LOC103846585	LOC100285492
			LOC102664273					LOC103850856	
								LOC103856008	
NIK1	NIK2	LOC4330602	LOC100305388	LOC25479984	LOC7466941	LOC100249555	LOC101245114	LRRII2	LOC100382590
		LOC4340743	LOC100790194	LOC25495505	LOC7468388	LOC100253129	LOC101246914	LOC103856175	LOC100280233
			LOC100797768	LOC25497639	LOC7483901		LOC101250403	LOC103875371	LOC100281584
			LOC100798412						
			LOC100804283						
			LOC100806650						
NIK3		LOC4327640	LOC100784164	LOC11407415	LOC7460771	LOC100256748	LOC101245842	LRRII1	LOC100272802
		LOC9268978	LOC100806943		LOC7469057		LOC101258453		LOC100383570
									LOC103635459
RLK902	RKL1	LOC4332106	LOC100781597	LOC11408124	LOC7474836	LOC100243943	LOC101247929	LOC103833000	LOC542104
		LOC4333893	LOC100788892	LOC11435862	LOC7487396	LOC100267283	LOC101254257	LOC103838993	LOC100285260
			LOC100801582	LOC25497283			LOC101268851	LOC103869641	LOC100285980
			LOC100818955						
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	AT3G47110	LOC9266358	LOC100777490	LOC11406710	LOC7463460	LOC100258860	LOC101250857	LOC103838692	LOC103628995
	AT3G47570	LOC9267517	LOC100778093	LOC11406756	LOC7468441	LOC100259050	LOC101251570	LOC103839158	LOC103634832
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HAK1	AT5G37450	LOC4325243 LOC9267172	LOC100777308 LOC100786467 LOC100799888 LOC100801035	LOC11410297 LOC11413754 LOC11435322	LOC7465186 LOC7465190 LOC7482611 LOC7498114	LOC100245012 LOC100265706	LOC101252112 LOC101264274	LOC103844004 LOC103855391	LOC103630498 LOC103630507 LOC103632695 LOC103646897
SOBIR1		LOC4340783	LOC100788151 LOC100811980	LOC25489526	LOC7453813	LOC100248492	LOC101252072 LOC101259548	LOC103857405 LOC103865167 LOC103865168	LOC100274364
PSKR1	PSKR2	LOC4330050 LOC4337364 LOC4337367 LOC4342205	LOC100789534 LOC100791334 LOC100807582	LOC25487312		LOC100254716 LOC100260504	LOC101246169 LOC101258171	LOC103844858 LOC103852007 LOC103854012	LOC109942164 LOC103627437 LOC100272954
BIR1		LOC4338797 LOC4350208	LOC100305365 LOC100801294 LOC100817267	LOC11428918 LOC25500213	LOC7464590 LOC7495475	LOC100854149 LOC100251471	LOC101261424	LOC103828382 LOC103874952	LOC100281404 LOC100285625
SARK	AT2G23950	LOC4345699	LOC100775565 LOC100797186	LOC11425481	LOC7485269 LOC7493367	LOC100244999	LOC101254706	LOC103861972 LOC103864508	LOC103643259
BRI1		LOC4324691	BRI1B BRI1A	LOC11441490	LOC7456279 LOC7477141	LOC100252647	CURL3	LOC103828047 LOC103835122 LOC103845289	LOC103636232 LOC103642983
BRL3	BRL1	LOC4346640 LOC9272003	BRL1B BRL1A	LOC25488505		LOC100249741	LOC101258083	LOC103832569 LOC103870174	LOC103632518 LOC103653350
ER	ERL2 ERL1	LOC4330905 LOC4340000 LOC4340427	LOC100305428 LOC100305433 LOC100499643 LOC100782307 LOC100795363 LOC100800185 LOC100804875 LOC100811653	LOC11428771 LOC25485110	LOC7476769 LOC7482132	LOC100256609 LOC100259283	LOC101244640 LOC101266437	LOC103842153 LOC103847083 LOC103874661	LOC100383941 LOC100279811 LOC100193598
CEPR2		LOC4325091 LOC4350138	LOC100789704	LOC11435226	LOC7455276	LOC100260256	LOC101250763 LOC101253498	LOC103650929 LOC103652818	LOC103650929 LOC103652818
KIN7	AT5G16590							LOC103843628 LOC103846319 LOC103851054 LOC103870882	

LRR1	AT3G02880	LOC103843628 LOC103846319 LOC103851054 LOC103870882

Table S3. Genetic tools in different crop plants in investigation of stress-related LRR-RLKs. Generated mutants defective in LRR-RLK genes in *N. benthamiana*, *S.lycopersicum*, *S.tuberosum*, S.*commersonii*, *O.sativa*, *T.aestivum*, *H.vulgare*, *B.distachyon* were taken from different research studies about role of LRR-RLK genes. OE-overexpression; Ri or RNAi – silenced mutant line, TRV- tobacco rattle virus, VIGS- Virus-induced gene silencing, p-promoter.

LRR-RLK gene	***N. benthamiana***	***S.lycopersicum/ S. tuberosum/ S. commersonii***	***O. sativa***	***T. aestivum /H.vulgare /B. distachyon***	**Reference**
BRI	*TRV:NbBRI1*	*SlBRI1* OE; *cu3* mutant; *StBRI1* in *bri1-5*; *StBRI1* Ri mutant	OE anti-*OsBRI1*; *d61-4* mutant	*OETaBRI1* in *Arabidopsis*; site direct modification of *TaBRI1* (Cas9/gRNA); silencing (VIGS) of *BRI1*; *BdBRI1-RNAi* mutants	[83,86-89,91-94,126, 181]
EFR	*AtEFR* into tobacco	*AtEFR* into tomato ; *AtEFR* into potato	*EFR:XA21* chimera in *Arabidopsis*	*pActEFR* into wheat	[98,99,100,103, 170]
ER	-	*pER::ER* (At) genomic in tomato	*pER::ER* (At) genomic in rice	*vasc1–1* mutants	[171-174]
			Loss-of-function mutants of *OsER1, OsER2*		
CLV1	-	*SIclv1* mutant	-	-	[175,176]
*SOBIR*1	OE of *NbSOBIR1* in tobacco	OE of *SlSOBIR1* in tobacco	-	-	[13,18,95,96]
	TRV:NbSOBIR1	*TRV:SlSOBIR1*			
	sobir1/*sobir1-like*				
BAK1	*NbSerk3A*	*SlSERK3A* silencing (VIGS)	Ectopic *AtBAK1*	-	[74-76,177]
	NbSerk3B	*SlSERK3B* silencing (VIGS)			
LRR1	-	-	*LRR1Ri*	*TaLRRK-6D*/*HvLRRK-6H*	[113,114,127]
SERK2	-	-	*OsSerk2Ri*	-	[77,79]
SERK1	-	-	*OEOsSerk1*	-	[78]
RLK1	-	-	*Ir-lrr (Ri)*	-	[178,179]
PEPR1	-	*PERK1* RNAi	-	-	[108, 180]
PSKR1	-	-	*OE OsPSKR1*	-	[104,105]
BRL3	-	-	D61-4 allele	-	[124,126]
ERL1	-	-	mutations in *OsERL*	-	[119,120]

Table S4 Potential interactions of stress-related LRR- RLKs (from LRR II family) with other LRR- RLKs. Formation of heterodimers were taken from ATTED database. The formation of heterodimers between the LRR- RLKs were labeled as "heterodimer". The inside box cross between two LRR- RLK genes; one from column and second from row. The method/s of identifying heterodimer formation was solid-phase assay. NA indicates data not available

	Co-receptors (LRR II)							
LRR- RLK	**SERK2**	**SERK1**	**SERK4/ BKK1**	**SERK3/ BAK1**	**SARK/Cik3**	**NIK1**	**NIK3/Cik1**	**Reference**
IOS1	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
PSY1R	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
SRF6	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
SRF7	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
SRF8	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
GHR1	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[153]
SRF2	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
SRF3	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
GSO1	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	[152,153]
BRL3	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
SARK/CIK3	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	heterodimer (solid-phase assay)	*NA*	[152]

BRL1	*NA*	*NA*	*NA*	heterodimer (anti tag CoIP, yeast two-hybrid assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[17, 152]
SERK5	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	*NA*	[152,153]
FEI1	heterodimer (solid-phase assay)	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	*NA*	[153]
SRF5	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
SRF1	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	*NA*	[152,153]
RLK902	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	NA	heterodimer (solid-phase assay)	[152,153]
NIK2	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	heterodimer (solid-phase assay)	NA	NA	[152,153]
PRK1	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	*NA*	heterodimer (solid-phase assay)	NA	[153]
NIK3	heterodimer (solid-phase assay)	*NA*	*NA*	heterodimer (solid-phase assay)	NA	NA	NA	[152,153]
PRK6	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	*NA*	*NA*	heterodimer (solid-phase assay)	[152,153]
PRK2A	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	[153]
PRK4	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	[152]
PRK5	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	[153]
MRLK	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	heterodimer (solid-phase assay)	[153]
BRL2	heterodimer (solid-phase assay)	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	[153]