Pyramiding *R* genes: genomic and genetic profiles of late-blight resistant interspecies potato hybrids

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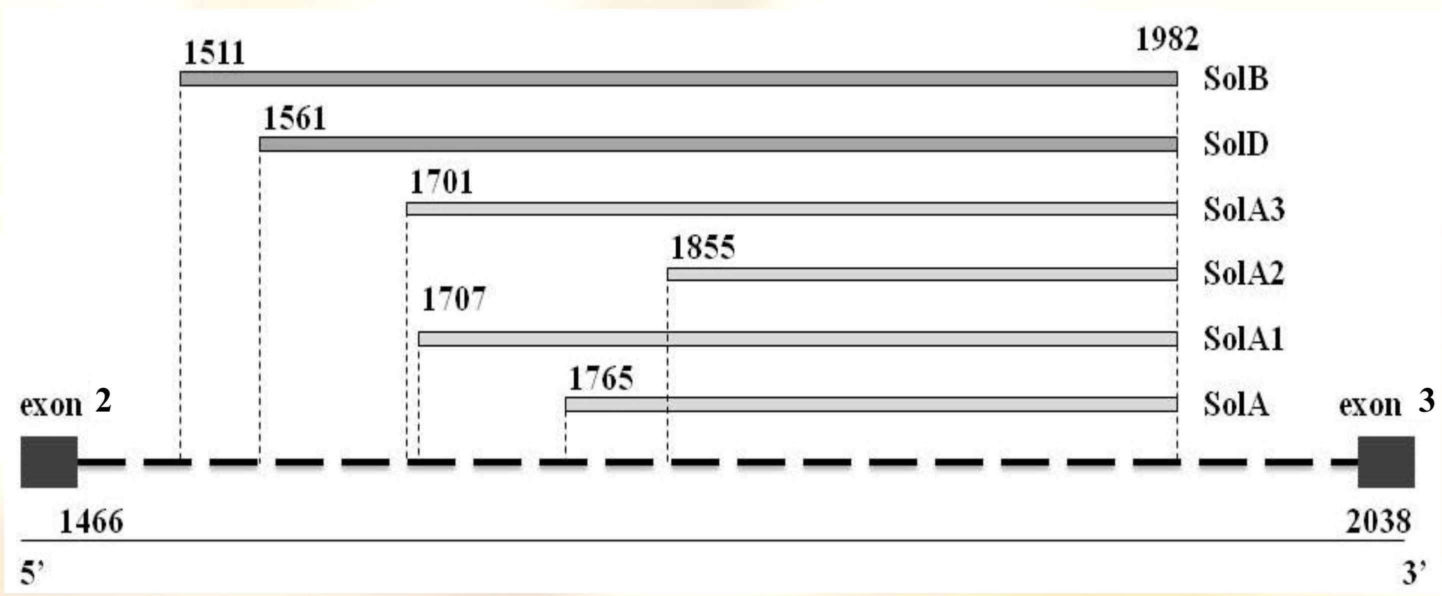
The study is focused on two sets of interspecies hybrids, which comprise germplasms from three to ten *Solanum* species and manifest high and medium high late blight (LB) resistance in detached leaf assays. SCAR markers for *Solanum* genomes A, B and presumably, D derived from low-copy *LEAFY* and conserved ortholog sequences (COSII) and SCAR markers for LB resistance genes *R1, R2, R3a, R3b* and *RB/Rpi-blb1* were used to screen seventeen hybrids. The patterns of genome and *R*-gene markers were in most cases explained by the tentative profiles of wild *Solanum* species that were reportedly employed in breeding these hybrids. Stacking *R* genes in these hybrids significantly enhanced their LB resistance.

a



b

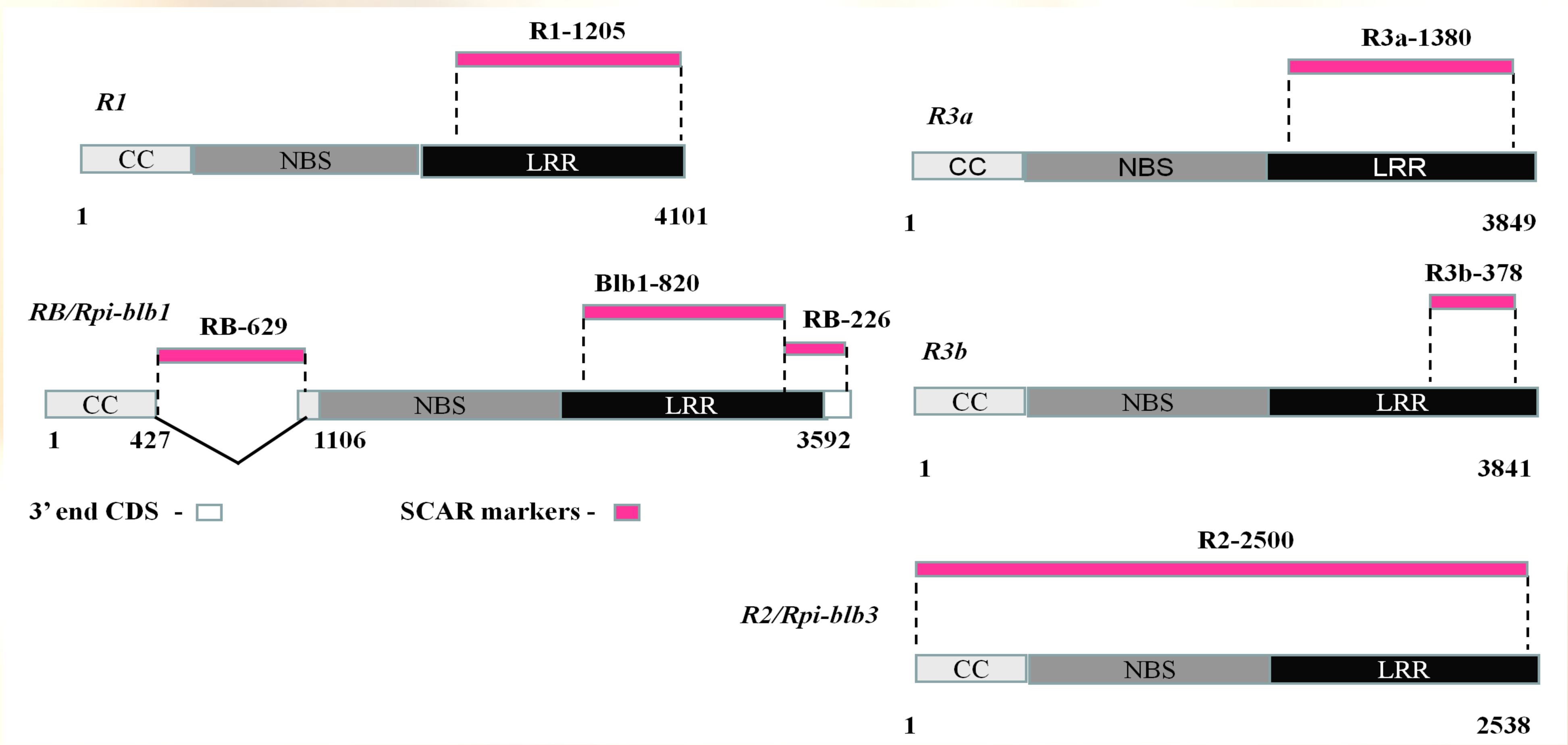


Fig. 1. SCAR markers of *Solanum* genomes (a) and *R* genes for LB resistance (b) For more details concerning *R*-gene markers, see the poster by Sokolova et al. at this meeting.

Table 1. Genome and *R*-gene patterns in interspecies hybrids bred in the Institute of Potato Husbandry (IPH) and the Institute of Plant Protection (IPP)

Hybrids	Pedigree (*Solanum* species)*	*Solanum* genomes	*R* genes for LB resistance established with SCAR markers	LB resistance**
IPH1	*chc, cmm, dms, mga, tbr*	A1-A3, D	*R3a, R3b*	MS/4
IPH2	*adg, chc, dms, sem, tbr*	A1-A3, D	*R3b*	S/3
IPH3	*chc, cmm, dms, mga, tbr*	A1-A3, D	*R1, R3a, R3b*	MR/7
IPH4	*dms, tbr*	A, D	*R1, R2, R3a, R3b*	MS/4
IPH5	*adg, chc, dms, sto, tbr*	A1, A3, D	*R1, R2, R3a, R3b*	MR/6
IPH6	*adg, chc, dms, tbr*	A1, A3, D	*R2, R3a, R3b*	MS/5
IPH7	*adg, chc, cmm, dms, edn, mga, ryb=phu, tbr*	A, A1, A3, D	*R2, R3a, R3b*	MR/6
IPH8	*dms, tbr*	A, A1, A3, D	*R2, R3b*	MS/5
IPH9	*dms, tbr*	A, A1, A3, D	*R1, R2, R3a, R3b*	R/8
IPP-10	*adg, dms, mcd, plt=sto, tbr, ver*	A1-A3, D	*R2, R3a, R3b, RB/Rpi-blb1*	MS/4
IPP-11	*adg, dms, mcd, plt=sto, tbr, ver*	A1-A3, B, D	*R2, R3a, RB/Rpi-blb1*	S/3
IPP-12	*adg, ber, dms, mcd, plt = sto, pnt, tbr, ver*	A, A1, A3, D	*R2, R3a, RB/Rpi-blb1*	MR/6
IPP-13	*adg, dms, pnt, tbr*	A, A1, A3, D	*R2, R3a*	MS/5
IPP-14	*adg, ber, dms, mcd, plt=sto, pnt, tbr, ver*	A1-A3, B, D	*R2, R3a*	MS/4
IPP-15	*adg, ber, dms, mcd, phu, plt=sto, pnt, tbr, ver, vrn*	A1-A3, B, D	*R2, R3a, RB/Rpi-blb1*	MR/6.5
IPP-16	*adg, ber, dms, mcd, plt=sto, tbr*	A1-A3, D	*R1, R2, R3a, RB/Rpi-blb1*	MR/7
IPP-18	*dms, mcd, pnt, tbr*	A1, A2, D	*R1, R2, R3a*	MS/4
Standard varieties				
Alpha	*tbr*	A	none	S/3
Bintje	*tbr*	A	none	S/3
Eeertstellung	*tbr*	A	none	S/3
Robijn	*tbr*	A	none	MS/4
Escort	*dms, tbr*	A, D	*R2, R3a, R3b*	MR/7
Sarpo Mira	*dms?, tbr*	A, D	*R3a, R3b*	R/8

*Abbreviations of *Solanum* species. *adg - S. andigenum, ber - S. berthaultii, chc - S. chacoense, cmm - S. commersonii, dms - S. demissum, edn - S. edinense, mcd – S. microdontum, mga - S. megistacrolobum, phu – S. phureja, plt - S. polytrichon = S. stoloniferum, pnt - S. pinnatisectum, ryb - S. rybinii = S. phureja, sem – S. semi-demissum, sto - S. stoloniferum; tbr - S. tuberosum, ver - S. verrucosum, vrn – S. vernei.*

**Grades/points of LB resistance in detached leaf assays: R, resistant (points 8-9), MR, moderately resistant (points 6-7), MS, moderately susceptible (points 4-5), S, susceptible (points ≤3).

Table 2. Some wild *Solanum* species reported in pedigrees of interspecies potato hybrids

Series	Species	Genomes established		*R* genes established by molecular studies**
		by classical genome analysis	by molecular technologies*	
Tuberosa	*S. berthaultii*		A1A1, A3A3	*R1, R3b*
	S. microdontum	AA	A1A1, A3A3	*R1, R3a, Rpi-mcd1*
	S. verrucosum	AA	AA, A1A1	*R3b, RBver*
Longipedicellata	*S. stoloniferum*	AABB	AABB, A1A1BB	*R1, R2/Rpi-blb3, R3a, R3b, Rpi-blb1*
Demissa	*S. demissum*	AADDD'D', A1A4[B,C,D]	AAPPPP, AABB, A1A1D	*R1, R2, R3a, R3b*
Bulbocastana	*S. bulbocastanum*	AbAb	BB	*R2/Rpi-blb3, R3a, R3b, Rpi-blb1, Rpi-blb2, RB-bt1*
Pinnatisecta	*S. pinnatisectum*	ApiApi	BpiBpi, BB	*R2, R3a, R3b*

*Compiled from [1, 3].
** For more details, see posters by Fadina et al. and by Sokolova et al. at this meeting.

Table 3. LB resistance of potato hybrids as affected by pyramiding the *R* genes

R-gene markers per plant	Groups of genotypes	Average resistance, points*
0	Standard cultivars free of wild *Solanum* germplasm Alpha, Bintje, Eeertstellung, Robijn	3.3
1	IPH2	4
2	IPH1, IPH8, IPP13, IPP14	4.5
3	IPH3, IPH6, IPH7, IPP1, IPP13, IPP15, IPP18	5.4
4	IPH4, IPH5, IPH9, IPP19, IPP16	5.8

*Detached-leaf assays.

Two sets of interspecies hybrids comprising germplasms from three to ten *Solanum* species were developed in the Institute of Potato Husbandry (IPH) and the Institute of Plant Protection (IPP). These hybrids displayed high and medium high late blight (LB) resistance in field and laboratory trials and are prospective donors for breeding new cultivars of manifest and durable LB resistance.

We screened these hybrids with SCAR markers for *Solanum* genomes A, B and D developed from *LEAFY* intron 2 (Fig. 1a) [1] and COSII sequences of several *Solanum* species reported by Rodriguez et al. [2] and cloned by the authors. The profiles of CC-NBS-LRR genes for LB resistance (*R* genes) were assessed with SCAR markers specific for *R1, R2/Rpi-blb3, R3a, R3b*, and *RB/Rpi-blb1* (Fig. 1b).

The evidence for the interspecies potato hybrids (Table 1) agrees fairly well with the previously established profiles of genomes and *R* genes in the dominant wild *Solanum* species employed in breeding these hybrids (Table 2).

We also compared the patterns of *R*-gene markers in the interspecies potato hybrids with their assessed in detached leaf trials with highly virulent complex race isolate of *Phytophthora infestans*. Four standard potato cultivars devoid of the *R* genes served as a control group (Table 3). The correlation between the number of *R*-gene markers and the points of LB resistance was highly significant, with the Spearman's coefficient of 0.62 (Fig. 2). While the race-specific *R* genes are commonly held to be defeated by *P. infestans,* our data support the concept that these genes, especially when stacked in one potato genotype, provide a discernible input to LB resistance [4].

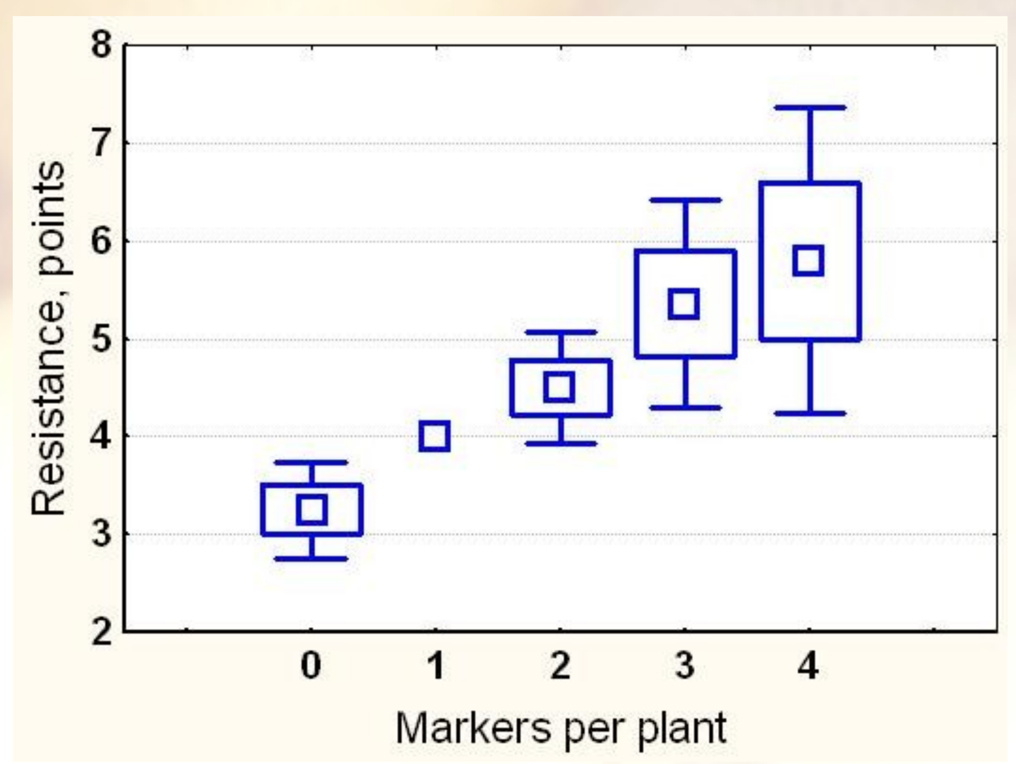


Fig. 2. The effect of stacking R genes in interspecies potato hybrids on their LB resistance in detached-leaf assays.

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