

De novo biosynthesis of plant lignans by synthetic yeast consortia

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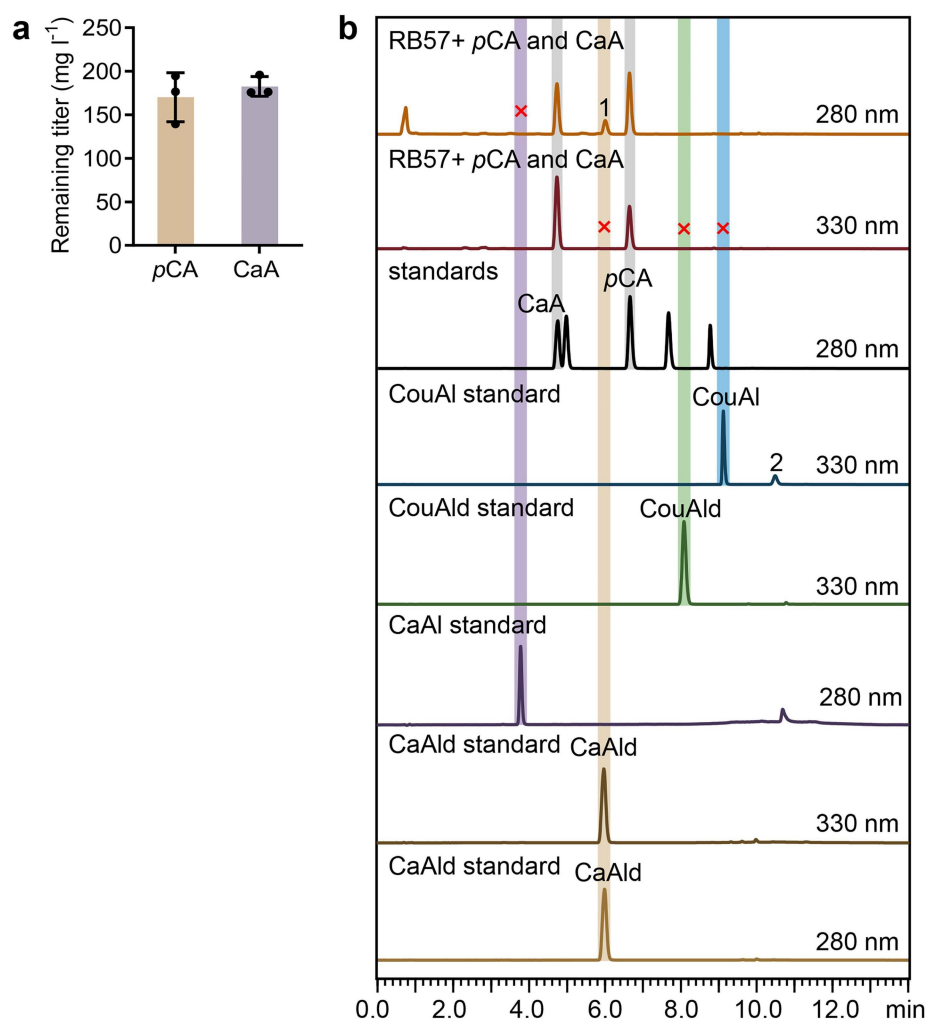
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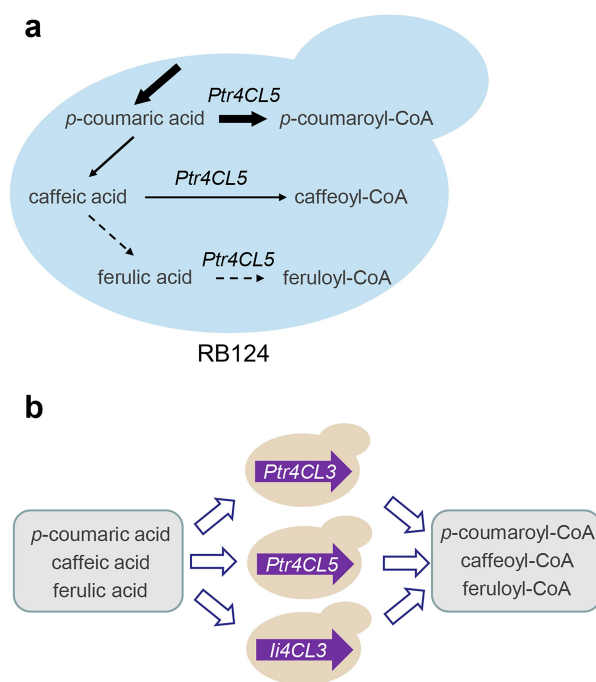
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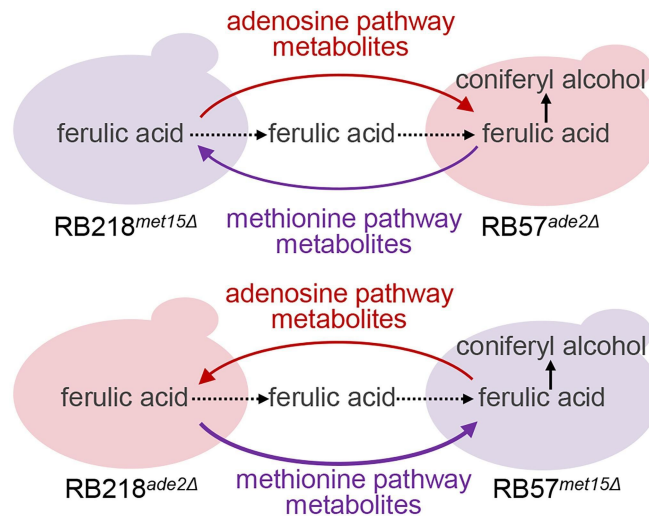
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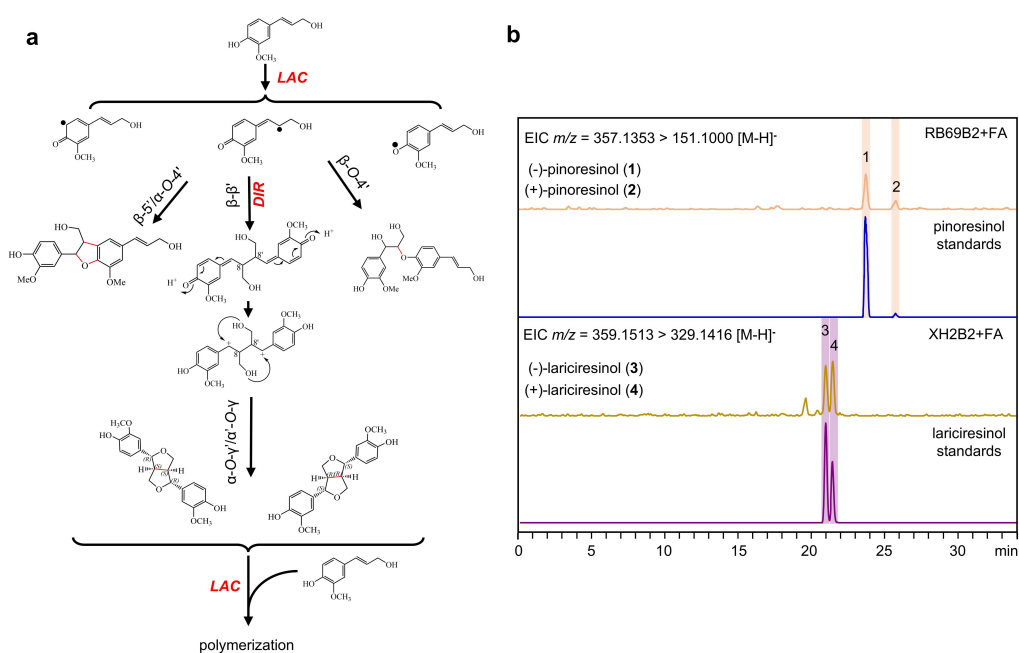
Supplementary Fig. 1 Functional analysis of the aromatic alcohol module. **a**, Residual titers of *pCA* and *CaA* in response to feeding the RB57 strain with 300 mg l⁻¹ *pCA* and *CaA*, respectively. **b**, Representative chromatographs of products synthesized by the strain expressing the aromatic alcohol module with the addition of 300 mg l⁻¹ *pCA* and *CaA*. *pCA*: *p*-coumaric acid, *CaA*: caffeic acid, *CouAl*: coumaroyl alcohol, *CouAld*: coumaroyl aldehyde, *CaAl*: caffeoyl alcohol, *CaAld*: caffeoyl aldehyde. Peak 1 is not *CaAld* due to the loss of absorption at 330 nm, and peak 2 is an impurity in the *CouAl* standard. All the strains were grown at 30°C in 20 ml of Delft-D medium. All the data are presented as the means of 3 biologically independent samples. The error bars indicate the SDs.



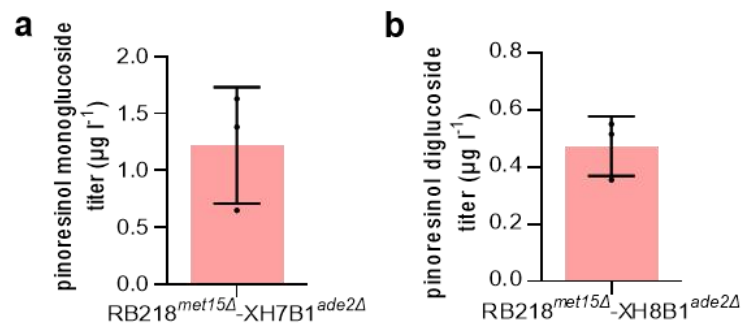
Supplementary Fig. 2 Substrate promiscuity of plant 4CL enzymes. **a**, Estimated metabolic flux distribution and reaction priority in the RB124 strain. The arrows represent metabolic intensity. The thick arrow represents strong metabolic flux, while the thin arrow represents weak metabolic flux. The dashed arrows represent very weak or interrupted metabolic flux. **b**, The promiscuous enzyme 4CL has a broad substrate spectrum of aromatic acids that can be used to generate corresponding CoA thioester intermediates. See **Fig. 1** legends for abbreviations of other enzymes and metabolites.



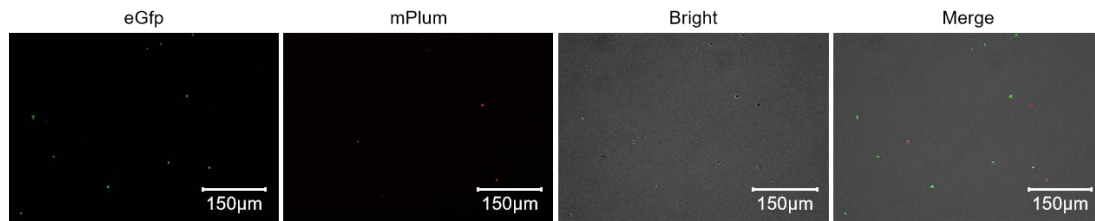
Supplementary Fig. 3 Two potential consortia for lignan synthesis. Two different consortia based on RB218^{met15Δ}-RB57^{ade2Δ} and RB218^{ade2Δ}-RB57^{met15Δ} performed differently in the synthesis of lignans.



Supplementary Fig. 4 Regioselectivity and stereoselectivity of *IiDir*. **a**, Mechanism underlying the bimolecular radical reactions of coniferyl alcohol catalyzed by laccase. Different region- and stereo-selective polymerizations of coniferyl alcohol may occur at different sites or at the same site to form various bimolecular isomers and polymers. *LAC3*: encoding laccase; *DIR*: encoding dirigent protein. **b**, Stereochemical characterization of pinoresinol and lariciresinol produced in yeast by feeding 100 mg l⁻¹ ferulic acid (FA). The products of RB69B2 strain contained (-)-pinoresinol (peak 1) and (+)-pinoresinol (peak 2), which is shown by the extracted ion chromatogram (EIC) in negative ion mode and compared to (±)-pinoresinol standards. Meanwhile, the products of XH2B2 strain contained (-)-lariciresinol (peak 3) and (+)-lariciresinol (peak 4), which is shown by the EIC in negative ion mode and compared to (±)-lariciresinol standards.



Supplementary Fig. 5 *De novo* biosynthesis of pinoresinol glucosides in yeast consortia. Titters of pinoresinol monoglucoside (**a**) and diglucoside (**b**) by yeast consortia. All the strains were grown at 30°C in 20 mL of Delft-D medium. All the data are presented as the means of 3 biologically independent samples, and the error bars show the SDs.



Supplementary Fig. 6 Representative fluorescence microscope images of yeast consortia. The proportions of two auxotrophic yeasts expressing different fluorescent proteins (eGfp and mPlum) in the yeast consortia consisting of RB218^{met15Δ-eGFP} and XH12^{ade2Δ-mPlum}. Scale bar: 150µm. Images were taken from three random fields to quantify the cell proportions.

Supplementary Table 1 *S. cerevisiae* strains used in this study. Shown in s separate file.

Strains	Genotype
CEN.PK113-11C	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ</i>
CEN.PK113-11C*	<i>MATa, MAL2-8C, SUC2, ura3Δ, his3Δ</i> =CEN.PK113-11C, <i>gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i>
RB52	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ii4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>AtCCR1-Sc^{OPT1}<THIS5)</i>
RB53	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ii4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i>
RB54	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ptr4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>AtCCR1-Sc^{OPT1}<THIS5)</i>
RB55	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ptr4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i>
RB56	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>AtCCR1-Sc^{OPT1}<THIS5)</i>
RB57	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i>
RB58	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ii4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i> =RB5 3, <i>XII5::(T_{CPSI}>PtrCCoAOMT1-Sc^{OPT1}<P_{GAL10/I}><T_{HIS5})</i>
RB59	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ii4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i> =RB5 3, <i>XII5::(T_{CPSI}>PtrCCoAOMT1-Sc^{OPT1}<P_{GAL10/I}>PtrAldOMT2-Sc^{OPT1}<T_{HIS5})</i>
RB60	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ptr4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i> =RB5 5, <i>XII5::(T_{CPSI}>PtrCCoAOMT1-Sc^{OPT1}<P_{GAL10/I}><T_{HIS5})</i>
RB61	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ptr4CL3-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i> =RB5 5, <i>XII5::(T_{CPSI}>PtrCCoAOMT1-Sc^{OPT1}<P_{GAL10/I}>PtrAldOMT2-Sc^{OPT1}<T_{HIS5})</i>
RB62	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(P_{TEF}-CAS9-T_{CYC1})</i> =CEN.PK113-11C*, <i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)</i> =RB5 7, <i>XII5::(T_{CPSI}>PtrCCoAOMT1-Sc^{OPT1}<P_{GAL10/I}><T_{HIS5})</i>

	<i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ,</i>
RB63	<i>XI5::(PTEF-CAS9-TCYC1)=CEN.PK113-11C*, XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(TCPSI>PtrCCoAOMT1-Sc^{OPT1}<P_{GAL10/I}>PtrAldOMT2-Sc^{OPT1}<T_{HIS5})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB68	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}><P_{GAL10/I}>CGL-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB69	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}><P_{GAL10/I}>TsLAC3-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB71	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}><P_{GAL10/I}>TvLAC1-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB68tr (RB68C)	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}><P_{GAL10/I}>trCGL-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB69tr (RB69C)	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}><P_{GAL10/I}>trTsLAC3-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB71tr (RB71C)	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}><P_{GAL10/I}>trTvLAC1-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB69A1	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}>liDIR1<P_{GAL10/I}>TsLAC3-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB69A2	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}>liDIR2<P_{GAL10/I}>TsLAC3-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB69B1	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}>trliDIR1<P_{GAL10/I}>trTsLAC3-Sc^{OPT1}<T_{IDPI})</i> <i>MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),</i>
RB69B2	<i>XIII::(PGAL7>Ptr4CL5-Sc^{OPT1}<TENO2)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5)=RB57, XII3::(T_{SPG5}>trliDIR2<P_{GAL10/I}>trTsLAC3-Sc^{OPT1}<T_{IDPI})</i>

- MATa*, *MAL2-8C*, *SUC2*, *ura3Δ*, *his3Δ*, *gal80Δ*,
XI5::(*P_{TEF}-CAS9-T_{CYC1}*)=*CEN.PK113-11C**, *aro10Δ*,
ARO10::(*T_{HIS3}*>*ScARO7^{G141S}-Sc^{OPT1}*<*P_{GAL10/1}*>*ScARO4^{K229L}-Sc^{OPT1}*<*T_{ENO2}*)>(*P_{GAL7}*>*EcAROL*<*T_{ADH1}*), *pdcc5Δ*,
PDC5::(*T_{CYC1}*>*FjTAL-Sc^{OPT1}*<*P_{GAL10/1}*>*SbPAL1-Sc^{OPT1}*<*T_{TDH2}*)>(*T_{FBA1}*>*AtCPR1-Sc^{OPT1}*<*P_{GAL7}*),
XII4::(*T_{PRM9}*>*PtrC4H2-Sc^{OPT1}*<*P_{GAL10/1}*>*PtrC4H1-Sc^{OPT1}*<*T_{PYK}*),
(*P_{GAL7}*>*PtrC3H3-Sc^{OPT1}*<*T_{DIT1}*),
X2::(*T_{PRM9}*>*PaHPAB-Sc^{OPT1}*<*P_{GAL10/1}*>*SeHPAC-Sc^{OPT1}*<*T_{HIS3}*),
XII5::(*T_{CPSI}*>*NtCOMT1-Sc^{OPT1}*<*P_{GAL10}*><*T_{HIS5}*)
MATa, *MAL2-8C*, *SUC2*, *ura3-52*, *his3Δ*, *gal80Δ*,
XI5::(*P_{TEF}-CAS9-T_{CYC1}*)=*CEN.PK113-11C**,
XII3::(*T_{SPG5}*><*P_{GAL10/1}*>*TsLAC3-Sc^{OPT1}*<*T_{IDP1}*)
MATa, *MAL2-8C*, *SUC2*, *ura3-52*, *his3Δ*, *gal80Δ*, *XI5::*(*P_{TEF}-CAS9-T_{CYC1}*),
XIII::(*P_{GAL7}*>*Ptr4CL5-Sc^{OPT1}*<*T_{ENO2}*)>(*T_{CPSI}*>*ScADH6*<*P_{GAL10/1}*>*PtrCCR2-Sc^{OPT1}*<*T_{HIS5}*)=RB5
7, ***pESC-PRX1pex1***
MATa, *MAL2-8C*, *SUC2*, *ura3-52*, *his3Δ*, *gal80Δ*, *XI5::*(*P_{TEF}-CAS9-T_{CYC1}*),
XIII::(*P_{GAL7}*>*Ptr4CL5-Sc^{OPT1}*<*T_{ENO2}*)>(*T_{CPSI}*>*ScADH6*<*P_{GAL10/1}*>*PtrCCR2-Sc^{OPT1}*<*T_{HIS5}*)=RB5
7, ***pESC-PRX2pex1***
MATa, *MAL2-8C*, *SUC2*, *ura3-52*, *his3Δ*, *gal80Δ*, *XI5::*(*P_{TEF}-CAS9-T_{CYC1}*),
XIII::(*P_{GAL7}*>*Ptr4CL5-Sc^{OPT1}*<*T_{ENO2}*)>(*T_{CPSI}*>*ScADH6*<*P_{GAL10/1}*>*PtrCCR2-Sc^{OPT1}*<*T_{HIS5}*)=RB5
7, ***pESC-PRX3pex1***
MATa, *MAL2-8C*, *SUC2*, *ura3-52*, *his3Δ*, *gal80Δ*, *XI5::*(*P_{TEF}-CAS9-T_{CYC1}*),
XIII::(*P_{GAL7}*>*Ptr4CL5-Sc^{OPT1}*<*T_{ENO2}*)>(*T_{CPSI}*>*ScADH6*<*P_{GAL10/1}*>*PtrCCR2-Sc^{OPT1}*<*T_{HIS5}*)=RB5
7, ***pESC-PRX4pex1***
MATa, *MAL2-8C*, *SUC2*, *ura3-52*, *his3Δ*, *gal80Δ*, *XI5::*(*P_{TEF}-CAS9-T_{CYC1}*),
XIII::(*P_{GAL7}*>*Ptr4CL5-Sc^{OPT1}*<*T_{ENO2}*)>(*T_{CPSI}*>*ScADH6*<*P_{GAL10/1}*>*PtrCCR2-Sc^{OPT1}*<*T_{HIS5}*)=RB5
7, ***pESC-PRX5pex1***
MATa, *MAL2-8C*, *SUC2*, *ura3Δ*, *his3Δ*, *gal80Δ*, *XI5::*(*P_{TEF}-CAS9-T_{CYC1}*),
aro10Δ,
ARO10::(*T_{HIS3}*>*ScARO7^{G141S}-Sc^{OPT1}*<*P_{GAL10/1}*>*ScARO4^{K229L}-Sc^{OPT1}*<*T_{ENO2}*)>(*P_{GAL7}*>*EcAROL*<*T_{ADH1}*), *pdcc5Δ*,
PDC5::(*T_{CYC1}*>*FjTAL-Sc^{OPT1}*<*P_{GAL10/1}*>*SbPAL1-Sc^{OPT1}*<*T_{TDH2}*)>(*T_{FBA1}*>*AtCPR1-Sc^{OPT1}*<*P_{GAL7}*), ***XII4::***(*T_{PRM9}*>*PtrC4H2-Sc^{OPT1}*<*P_{GAL10/1}*>*PtrC4H1-Sc^{OPT1}*<*T_{PYK}*),
(*P_{GAL7}*>*PtrC3H3-Sc^{OPT1}*<*T_{DIT1}*),
X2::(*T_{PRM9}*>*PaHPAB-Sc^{OPT1}*<*P_{GAL10/1}*>*SeHPAC-Sc^{OPT1}*<*T_{HIS3}*),
XII5::(*T_{CPSI}*>*NtCOMT1-Sc^{OPT1}*<*P_{GAL10}*><*T_{HIS5}*)=RB79, ***XIII::***(*P_{GAL7}*>*Ptr4CL5-Sc^{OPT1}*<*T_{ENO2}*)>(*T_{CPSI}*>*ScADH6*<*P_{GAL10/1}*>*PtrCCR2-Sc^{OPT1}*<*T_{HIS5}*)

	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>aro10Δ</i>, <i>ARO10::</i>(<i>T_{HIS3}</i>><i>ScARO7^{G141S}-Sc^{OPT1}</i><<i>P_{GAL10/1}</i>><i>ScARO4^{K229L}-Sc^{OPT1}</i><<i>T_{ENO2}</i>)<(P <i>GAL7</i>><i>EcAROL</i><<i>T_{ADH1}</i>), <i>pdz5Δ</i>, <i>PDC5::</i>(<i>T_{CYC1}</i>><i>FjTAL-Sc^{OPT1}</i><<i>P_{GAL10/1}</i>><i>SbPAL1-Sc^{OPT1}</i><<i>T_{TDH2}</i>)<(T<i>FBA1</i>><i>AtCPR</i> <i>1-Sc^{OPT1}</i><<i>P_{GAL7}</i>), <i>XII4::</i>(<i>T_{PRM9}</i>><i>PtrC4H2-Sc^{OPT1}</i><<i>P_{GAL10/1}</i>><i>PtrC4H1-Sc^{OPT1}</i><<i>T_{PYK}</i>)<(P<i>GAL7</i>><i>PtrC3</i> <i>H3-Sc^{OPT1}</i><<i>T_{DIT1}</i>), <i>X2::</i>(<i>T_{PRM9}</i>><i>PaHPAB-Sc^{OPT1}</i><<i>P_{GAL10/1}</i>><i>SeHPAC-Sc^{OPT1}</i><<i>T_{HIS3}</i>), <i>XIII::</i>(<i>P_{GAL7}</i>><i>ScARO1</i><<i>T_{ENO2}</i>)<(T<i>CPS1</i>><i>ScARO2</i><<i>P_{GAL10/1}</i>><i>ScARO3</i><<i>T_{HIS5}</i>), <i>gpp1Δ</i>, <i>GPPI::</i>(<i>TENO2T_{ENO2}</i>><i>CkPTA-Sc^{OPT1}</i><<i>P_{GAL10/1}</i>><i>LmXFPK-Op^{OPT1}</i><<i>T_{HIS5}</i>), <i>XII5::</i>(<i>T_{CPS1}</i>><i>NtCOMT1-Sc^{OPT1}</i><<i>P_{GAL10/1}</i>><i>NtCOMT1-Op^{OPT1}</i><<i>T_{HIS5}</i>), <i>XI8::</i>(<i>T_{CPS1}</i>><i>NtCOMT1-Sc^{OPT1}</i><<i>P_{GAL10/1}</i>><i>NtCOMT1-Op^{OPT1}</i><<i>T_{HIS5}</i>), <i>XI7::</i>(<i>T_{PRM9}</i>><<i>P_{GAL10}</i>><i>ScTAL1</i><<i>T_{PYK1}</i>), <i>XI6::</i>(<i>P_{GAL7}</i>><i>ScTKL1</i><<i>T_{ENO2}</i>), <i>hoΔ</i>, (<i>T_{HSP26}</i>><i>ScMET6</i><<i>P_{GAL10/1}</i>><i>MTFHR</i> <i>chimera1-Sc^{OPT1}</i><<i>T_{PDC6}</i>)<(P<i>GAL7</i>><i>LiMETK1-Sc^{OPT1}</i><<i>T_{UBX6}</i>), <i>V3::</i>(<i>T_{PRM9}</i>><i>ScADO1</i><<i>P_{GAL10/1}</i>><i>ScSAH1</i><<i>T_{PYK1}</i>)
RB218	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>)
his3Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>),<i>met15Δ</i>
met15Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>),<i>ade2Δ</i>
ade2Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>),<i>thr4Δ</i>
thr4Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>),<i>ilv1Δ</i>
ilv1Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>),<i>ser2Δ</i>
ser2Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>), <i>pro2Δ</i>
pro2Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>),<i>arg4Δ</i>
arg4Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>, <i>HIS3::</i>(<i>P_{HIS3}</i>><i>HIS3</i><<i>T_{HIS3}</i>), <i>ura3Δ</i>, <i>URA3::</i> (<i>P_{URA3}</i>> <i>URA3</i><<i>T_{URA3}</i>),<i>trp1Δ</i>
trp1Δ	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P_{TEF}-CAS9-T_{CYC1}</i>)=<i>CEN.PK113-11C*</i>, <i>his3Δ</i>,

HIS3:: (P_{HIS3}>HIS3<T_{HIS3}), ura3Δ, URA3:: (P_{URA3}> URA3<T_{URA3}), trp1Δ

MATa, MAL2-8C, SUC2, ura3Δ, his3Δ, gal80Δ,
lys2Δ *XI5:: (P_{TEF}-CAS9-T_{CYC1})=CEN.PK113-11C*, his3Δ,*
HIS3:: (P_{HIS3}>HIS3<T_{HIS3}), ura3Δ, URA3:: (P_{URA3}> URA3<T_{URA3}), lys2Δ
MATa, MAL2-8C, SUC2, ura3Δ, his3Δ, gal80Δ,
leu2Δ *XI5:: (P_{TEF}-CAS9-T_{CYC1})=CEN.PK113-11C*, his3Δ,*
HIS3:: (P_{HIS3}>HIS3<T_{HIS3}), ura3Δ, URA3:: (P_{URA3}> URA3<T_{URA3}), leu2Δ
MATa, MAL2-8C, SUC2, ura3Δ, his3Δ, gal80Δ, XI5:: (P_{TEF}-CAS9-T_{CYC1}),
aro10Δ,
ARO10:: (T_{HIS3}>ScARO7^{G141S}-Sc^{OPT1}<P_{GAL10/I}>ScARO4^{K229L}-Sc^{OPT1}<T_{ENO2}) + (P_{GAL}
γ>EcAROL<T_{ADH1}), pdc5Δ,
PDC5:: (T_{CYC1}>FjTAL-Sc^{OPT1}<P_{GAL10/I}>SbPALI-Sc^{OPT1}<T_{TDH2}) + (T_{FBA1}>AtCPR1-
Sc^{OPT1}<P_{GAL7}),
XII4:: (T_{PRM9}>PtrC4H2-Sc^{OPT1}<P_{GAL10/I}>PtrC4H1-Sc^{OPT1}<T_{PYK}) + (P_{GAL7}>PtrC3H3
-Sc^{OPT1}<T_{DIT1}), X2:: (T_{PRM9}>PaHPAB-Sc^{OPT1}<P_{GAL10/I}>SeHPAC-Sc^{OPT1}<T_{HIS3}),
RB218^{met15Δ} *XIII:: (P_{GAL7}>ScAROI<T_{ENO2}) + (T_{CPSI}>ScARO2<P_{GAL10/I}>ScARO3<T_{HIS3}), gpp1Δ,*
GPPI:: (T_{ENO2}T_{ENO2}>CkPTA-Sc^{OPT1}<P_{GAL10/I}>LmXFPK-Op^{OPT1}<T_{HIS3}),
XII5:: (T_{CPSI}>NtCOMT1-Sc^{OPT1}<P_{GAL10/I}>NtCOMT1-Op^{OPT1}<T_{HIS3}),
XI8:: (T_{CPSI}>NtCOMT1-Sc^{OPT1}<P_{GAL10/I}>NtCOMT1-Op^{OPT1}<T_{HIS3}),
XI7:: (T_{PRM9}><P_{GAL10}>ScTALI<T_{PYK1}), XI6:: (P_{GAL7}>ScTKLI<T_{ENO2}), hoΔ,
(T_{HSP26}>ScMET6<P_{GAL10/I}>MTFHR
chimera1-Sc^{OPT1}<T_{PDC6}) + (P_{GAL7}>LiMETKI-Sc^{OPT1}<T_{UBX6}),
V3:: (T_{PRM9}>ScADOI<P_{GAL10/I}>ScSAHI<T_{PYK1})=RB218, met15Δ
MATa, MAL2-8C, SUC2, ura3Δ, his3Δ, gal80Δ, XI5:: (P_{TEF}-CAS9-T_{CYC1}),
aro10Δ,
ARO10:: (T_{HIS3}>ScARO7^{G141S}-Sc^{OPT1}<P_{GAL10/I}>ScARO4^{K229L}-Sc^{OPT1}<T_{ENO2}) + (P_{GAL}
γ>EcAROL<T_{ADH1}), pdc5Δ,
PDC5:: (T_{CYC1}>FjTAL-Sc^{OPT1}<P_{GAL10/I}>SbPALI-Sc^{OPT1}<T_{TDH2}) + (T_{FBA1}>AtCPR1-
Sc^{OPT1}<P_{GAL7}),
XII4:: (T_{PRM9}>PtrC4H2-Sc^{OPT1}<P_{GAL10/I}>PtrC4H1-Sc^{OPT1}<T_{PYK}) + (P_{GAL7}>PtrC3H3
-Sc^{OPT1}<T_{DIT1}), X2:: (T_{PRM9}>PaHPAB-Sc^{OPT1}<P_{GAL10/I}>SeHPAC-Sc^{OPT1}<T_{HIS3}),
RB218^{met15Δ} *XIII:: (P_{GAL7}>ScAROI<T_{ENO2}) + (T_{CPSI}>ScARO2<P_{GAL10/I}>ScARO3<T_{HIS3}), gpp1Δ,*
GPPI:: (T_{ENO2}T_{ENO2}>CkPTA-Sc^{OPT1}<P_{GAL10/I}>LmXFPK-Op^{OPT1}<T_{HIS3}),
XII5:: (T_{CPSI}>NtCOMT1-Sc^{OPT1}<P_{GAL10/I}>NtCOMT1-Op^{OPT1}<T_{HIS3}),
XI8:: (T_{CPSI}>NtCOMT1-Sc^{OPT1}<P_{GAL10/I}>NtCOMT1-Op^{OPT1}<T_{HIS3}),
XI7:: (T_{PRM9}><P_{GAL10}>ScTALI<T_{PYK1}), XI6:: (P_{GAL7}>ScTKLI<T_{ENO2}), hoΔ,
(T_{HSP26}>ScMET6<P_{GAL10/I}>MTFHR
chimera1-Sc^{OPT1}<T_{PDC6}) + (P_{GAL7}>LiMETKI-Sc^{OPT1}<T_{UBX6}),
V3:: (T_{PRM9}>ScADOI<P_{GAL10/I}>ScSAHI<T_{PYK1}), met15Δ=RB218^{met15Δ},
XII3:: (P_{UAS-TDH3}>eGFP-opt<T_{PYK1})

	<i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3Δ</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P</i>_{TEF}-<i>CAS9</i>-<i>T</i>_{CYC1}), <i>aro10Δ</i>, <i>ARO10::</i>(<i>T</i>_{HIS3}><i>ScARO7</i>^{G141S}-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10/1}><i>ScARO4</i>^{K229L}-<i>Sc</i>^{OPT1}<<i>T</i>_{ENO2})+(<i>P</i>_{GAL7}><i>EcAROL</i><<i>T</i>_{ADH1}), <i>pdC5Δ</i>, <i>PDC5::</i>(<i>T</i>_{CYC1}><i>FjTAL</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10/1}><i>SbPAL1</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{TDH2})+(<i>T</i>_{FBA1}><i>AtCPR1</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL7}), <i>XII4::</i>(<i>T</i>_{PRM9}><i>PtrC4H2</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10/1}><i>PtrC4H1</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{PYK})+(<i>P</i>_{GAL7}><i>PtrC3H3</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{DIT1}), <i>X2::</i>(<i>T</i>_{PRM9}><i>PaHPAB</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10/1}><i>SeHPAC</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{HIS3}), <i>XIII::</i>(<i>P</i>_{GAL7}><i>ScARO1</i><<i>T</i>_{ENO2})+(<i>T</i>_{CPS1}><i>ScARO2</i><<i>P</i>_{GAL10/1}><i>ScARO3</i><<i>T</i>_{HIS3}), <i>gpp1Δ</i>, <i>GPPI::</i>(<i>TENO2</i><i>T</i>_{ENO2}><i>CkPTA</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10/1}><i>LmXFPK</i>-<i>Op</i>^{OPT1}<<i>T</i>_{HIS5}), <i>XII5::</i>(<i>T</i>_{CPS1}><i>NtCOMT1</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10/1}><i>NtCOMT1</i>-<i>Op</i>^{OPT1}<<i>T</i>_{HIS5}), <i>XI8::</i>(<i>T</i>_{CPS1}><i>NtCOMT1</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10/1}><i>NtCOMT1</i>-<i>Op</i>^{OPT1}<<i>T</i>_{HIS5}), <i>XI7::</i>(<i>T</i>_{PRM9}><<i>P</i>_{GAL10}><i>ScTAL1</i><<i>T</i>_{PYK1}), <i>XI6::</i>(<i>P</i>_{GAL7}><i>ScTKL1</i><<i>T</i>_{ENO2}), <i>hoΔ</i>, (<i>T</i>_{HSP26}><i>ScMET6</i><<i>P</i>_{GAL10/1}><i>MTFHR chimera1</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{PDC6})+(<i>P</i>_{GAL7}><i>LiMETK1</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{UBX6}), <i>V3::</i>(<i>T</i>_{PRM9}><i>ScADO1</i><<i>P</i>_{GAL10/1}><i>ScSAH1</i><<i>T</i>_{PYK1})=RB218, <i>ade2Δ</i> <i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3-52</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P</i>_{TEF}-<i>CAS9</i>-<i>T</i>_{CYC1}), <i>XIII::</i>(<i>P</i>_{GAL7}><i>Ptr4CL5</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{ENO2})+(<i>T</i>_{CPS1}><i>ScADH6</i><<i>P</i>_{GAL10/1}><i>PtrCCR2</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{HIS5})=RB57, <i>met15Δ</i> <i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3-52</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P</i>_{TEF}-<i>CAS9</i>-<i>T</i>_{CYC1}), <i>XIII::</i>(<i>P</i>_{GAL7}><i>Ptr4CL5</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{ENO2})+(<i>T</i>_{CPS1}><i>ScADH6</i><<i>P</i>_{GAL10/1}><i>PtrCCR2</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{HIS5})=RB57, <i>ade2Δ</i> <i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3-52</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P</i>_{TEF}-<i>CAS9</i>-<i>T</i>_{CYC1}), <i>XIII::</i>(<i>P</i>_{GAL7}><i>Ptr4CL5</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{ENO2})+(<i>T</i>_{CPS1}><i>ScADH6</i><<i>P</i>_{GAL10/1}><i>PtrCCR2</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{HIS5}), <i>XII3::</i>(<i>T</i>_{SPG5}><i>trLiDIR1</i><<i>P</i>_{GAL10/1}><i>trTsLAC3</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{IDP1})=RB69B1, <i>XI3::</i>(<i>T</i>_{PRM5}><i>AtPRR</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10}><<i>T</i>_{LSC2}) <i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3-52</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P</i>_{TEF}-<i>CAS9</i>-<i>T</i>_{CYC1}), <i>XIII::</i>(<i>P</i>_{GAL7}><i>Ptr4CL5</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{ENO2})+(<i>T</i>_{CPS1}><i>ScADH6</i><<i>P</i>_{GAL10/1}><i>PtrCCR2</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{HIS5}), <i>XII3::</i>(<i>T</i>_{SPG5}><i>trLiDIR2</i><<i>P</i>_{GAL10/1}><i>trTsLAC3</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{IDP1})=RB69B2, <i>XI3::</i>(<i>T</i>_{PRM5}><i>AtPRR</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10}><<i>T</i>_{LSC2}) <i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3-52</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P</i>_{TEF}-<i>CAS9</i>-<i>T</i>_{CYC1}), <i>XIII::</i>(<i>P</i>_{GAL7}><i>Ptr4CL5</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{ENO2})+(<i>T</i>_{CPS1}><i>ScADH6</i><<i>P</i>_{GAL10/1}><i>PtrCCR2</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{HIS5}), <i>XII3::</i>(<i>T</i>_{SPG5}><i>trLiDIR1</i><<i>P</i>_{GAL10/1}><i>trTsLAC3</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{IDP1})=RB69B1, <i>XI3::</i>(<i>T</i>_{PRM5}><i>IiPLR1</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10}><<i>T</i>_{LSC2}) <i>MATa</i>, <i>MAL2-8C</i>, <i>SUC2</i>, <i>ura3-52</i>, <i>his3Δ</i>, <i>gal80Δ</i>, <i>XI5::</i>(<i>P</i>_{TEF}-<i>CAS9</i>-<i>T</i>_{CYC1}), <i>XIII::</i>(<i>P</i>_{GAL7}><i>Ptr4CL5</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{ENO2})+(<i>T</i>_{CPS1}><i>ScADH6</i><<i>P</i>_{GAL10/1}><i>PtrCCR2</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{HIS5}), <i>XII3::</i>(<i>T</i>_{SPG5}><i>trLiDIR2</i><<i>P</i>_{GAL10/1}><i>trTsLAC3</i>-<i>Sc</i>^{OPT1}<<i>T</i>_{IDP1})=RB69B2, <i>XI3::</i>(<i>T</i>_{PRM5}><i>IiPLR1</i>-<i>Sc</i>^{OPT1}<<i>P</i>_{GAL10}><<i>T</i>_{LSC2})
RB218 ^{ade2Δ}	
RB57 ^{met15Δ}	
RB57 ^{ade2Δ}	
XH1B1	
XH1B2	
XH2B1	
XH2B2	

	<i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH3B1	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR1</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B1, <i>XI3::</i>(T_{PRM5}>ShPLR-Sc^{OPT1}<P_{GAL10}><T_{LSC2}) <i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH3B2	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR2</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B2, <i>XI3::</i>(T_{PRM5}>ShPLR-Sc^{OPT1}<P_{GAL10}><T_{LSC2}) <i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH4	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR2</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B2, <i>XI3::</i>(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B2<T_{LSC2}) <i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH5	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR2</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B2, <i>XI3::</i>(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B5a<T_{LSC2}) <i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH6	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR2</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B2, <i>XI3::</i>(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B5b<T_{LSC2}) <i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH7B1	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR1</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B1, <i>XI3::</i>(T_{PRM5}><P_{GAL10}>IiUGT71B2<T_{LSC2}) <i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH8B1	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR1</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B1, <i>XI3::</i>(T_{PRM5}><P_{GAL10}>IiUGT71B5a<T_{LSC2}) <i>MATa</i> , <i>MAL2-8C</i> , <i>SUC2</i> , <i>ura3-52</i> , <i>his3Δ</i> , <i>gal80Δ</i> , <i>XI5::</i> (PTEF-CAS9-TCYC1), <i>XIII::</i> (PGAL7>Ptr4CL5-
XH9B1	Sc ^{OPT1} <TENO2>)+(TCPS1>ScADH6<PGAL10/1>PtrCCR2-Sc ^{OPT1} <THIS5>), <i>XII3::</i> (T _{SPG5} >tr <i>LiDIR1</i> <P _{GAL10/1} >tr <i>TsLAC3</i> -Sc ^{OPT1} <T _{IDP1})=RB69B1, <i>XI3::</i>(T_{PRM5}><P_{GAL10}>IiUGT71B5b<T_{LSC2})

- MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::*(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/1>PtrCCR2-Sc^{OPT1}<THIS5>),
 XH12 *XII3::*(T_{SPG5}>trIiDIR2<P_{GAL10/1}>trTsLAC3-Sc^{OPT1}<T_{IDP1}>),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B5b<T_{LSC2}>)=XH6,
***III::*(T_{PRM5}>IiUGT71B5b<P_{GAL10}>IiUGT71B5b<T_{LSC2}>)**
MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/1>PtrCCR2-Sc^{OPT1}<THIS5>),
 XH13 *XII3::*(T_{SPG5}>trIiDIR1<P_{GAL10/1}>trTsLAC3-Sc^{OPT1}<T_{IDP1}>),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B2<T_{LSC2}>)=XH7B1,
***III::*(T_{PRM5}>IiUGT71B2<P_{GAL10}>IiUGT71B2<T_{LSC2}>)**
MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/1>PtrCCR2-Sc^{OPT1}<THIS5>),
 XH14 *XII3::*(T_{SPG5}>trIiDIR1<P_{GAL10/1}>trTsLAC3-Sc^{OPT1}<T_{IDP1}>),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B2<T_{LSC2}>)=XH8B1,
***III::*(T_{PRM5}>IiUGT71B5a<P_{GAL10}>IiUGT71B5a<T_{LSC2}>)**
MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/1>PtrCCR2-Sc^{OPT1}<THIS5>),
 XH18 *XII3::*(T_{SPG5}>trIiDIR2<P_{GAL10/1}>trTsLAC3-Sc^{OPT1}<T_{IDP1}>),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B5b<T_{LSC2}>),
***III::*(T_{PRM5}>IiUGT71B5b<P_{GAL10}>IiUGT71B5b<T_{LSC2}>)=XH12,**
***XII5::*(T_{CPSI}>ScUGP1<P_{GAL10}>ScPGM1<T_{HIS5}>)**
MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/1>PtrCCR2-Sc^{OPT1}<THIS5>),
 XH12^{met15Δ} *XII3::*(T_{SPG5}>trIiDIR2<P_{GAL10/1}>trTsLAC3-Sc^{OPT1}<T_{IDP1}>),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B5b<T_{LSC2}>),
III::*(T_{PRM5}>IiUGT71B5b<P_{GAL10}>IiUGT71B5b<T_{LSC2}>)=XH12, ***met15Δ
MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/1>PtrCCR2-Sc^{OPT1}<THIS5>),
 XH12^{ade2Δ} *XII3::*(T_{SPG5}>trIiDIR2<P_{GAL10/1}>trTsLAC3-Sc^{OPT1}<T_{IDP1}>),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B5b<T_{LSC2}>),
III::*(T_{PRM5}>IiUGT71B5b<P_{GAL10}>IiUGT71B5b<T_{LSC2}>)=XH12, ***ade2Δ
MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/1>PtrCCR2-Sc^{OPT1}<THIS5>),
 XH12^{ade2Δ} *XII3::*(T_{SPG5}>trIiDIR2<P_{GAL10/1}>trTsLAC3-Sc^{OPT1}<T_{IDP1}>),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B5b<T_{LSC2}>),
***III::*(T_{PRM5}>IiUGT71B5b<P_{GAL10}>IiUGT71B5b<T_{LSC2}>), *ade2Δ*=XH12^{ade2Δ},**
XII3::*(P_{UAS-TDH3}>mPlum-opt<T_{PYK1}>)***

MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 XH7B1^{*ade2Δ*} Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5),
XII3::(T_{SPG5}>tr*LiDIR1*<P_{GAL10/I}>tr*TsLAC3*-Sc^{OPT1}<T_{IDP1}),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B2<T_{LSC2})=XH7B1, ***ade2Δ***
MATa, MAL2-8C, SUC2, ura3-52, his3Δ, gal80Δ, XI5::(PTEF-CAS9-TCYC1),
XIII::(PGAL7>Ptr4CL5-
 XH8B1^{*ade2Δ*} Sc^{OPT1}<TENO2>)+(TCPSI>ScADH6<PGAL10/I>PtrCCR2-Sc^{OPT1}<THIS5),
XII3::(T_{SPG5}>tr*LiDIR1*<P_{GAL10/I}>tr*TsLAC3*-Sc^{OPT1}<T_{IDP1}),
XI3::(T_{PRM5}>IiPLR1-Sc^{OPT1}<P_{GAL10}>IiUGT71B2<T_{LSC2})=XH8B1, ***ade2Δ***

Supplementary Table 2 The parameters used for HPLC analysis of phenolic acids and coniferyl alcohol.

Time (min)	A (%)	B (%)
0	95	5
3	90	10
4	88	12
5	88	12
6	85	15
7	85	15
10	40	60
12	95	5
14	95	5

Column: 3×100 mm 2.7 µm Poroshell 120 EC-C18 (Agilent)

Flow rate: 0.8 ml min⁻¹

Mobile phases A: H₂O+0.05% HCOOH

Mobile phases B: acetonitrile+0.05% HCOOH

Wavelength: 280 nm and 330 nm

Supplementary Table 3 The parameters used for HPLC-MS/MS analysis of lignans.

Mass spectrometry detection conditions for lignans in HPLC-MS/MS negative ion mode.

Compound Name	Precursor ion	Product ion	Dwell	Fragmentor	Collision Energy	Polarity
trans-Ferulic acid (FA)	193	133.8	50	30	21	Negative
Coniferyl alcohol (CoAl)	179	146	50	75	5	Negative
(±)-Pinoresinol	357.1	151.1	50	135	20	Negative
lariciresinol	359.2	329	50	100	3	Negative
Secoisolariciresinol	361.1	164.9	50	135	30	Negative
(+)-Lariciresinol	521.2	359.1	50	130	10	Negative
4-O-β-D-glucoside						
lariciresinol diglucoside (LDG)	683.2	521.2	50	110	12	Negative
(+)-Pinoresinol						
4-O-glucoside	519.1	357	50	120	9	Negative
Pinoresinol diglucoside	681.2	519.2	50	120	7	Negative
Secoisolariciresinol						
monoglucoside	523.2	361.2	50	100	26	Negative
Secoisolariciresinol						
diglucoside	685.3	523.1	50	240	35	Negative

Mobile phase condition.

Time (min)	A (%)	B (%)
0	95	5
2	80	20
6	78	22
12	75	25
23	5	95

Column: 3 × 100 mm 2.7 μm Poroshell 120 EC-C18 (Agilent)

Flow rate: 0.3 ml min⁻¹Mobile phases A: H₂O+0.05% HCOOH

Mobile phases B: acetonitrile+0.05% HCOOH

Post time: 5 min

Supplementary Data 1 Primers used in this study.

No	Primer name	Sequence (5'-3')
p3	HIS3t-F(3)	TGACACCGATTATTTAAAGCTGC
p4	HIS3t-R(4)	CTGTTATTTCTGGCACTTCTTGG
p7	GAL1/10p-F(7)	TTTGTTATATTGAATTTTCAAAAATTCTTACTTTTTTTT TG
p8	GAL1/10p-R(8)	TTTGTATAGTTTTTCTCCTTGACGTTAAAG
p11	ENO2t-F(11)	AGTGCTTTTAACTAAGAATTATTAGTCTTTTCTGC
p12	ENO2t-R(12)	AGGTATCATCTCCATCTCCCATATGC
p13	GAL7p-F(13)	TTTGCCAGCTTACTATCCTTCTTG
p14	GAL7p-R(14)	TTTTGAGGGAATATTCAACTGTTTTTTTTTATCATG
p19	ADH1t-F(19)	GCGAATTTCTTATGATTTATGATTTTATTATTAAATA AGTTAT
p34	P1(34)	GCGGTTAGTCTCCTTCGGTCCTCCGATCGTTGTCAGAA GTAAGTTGGCCGCAGTGTTATC
p35	P2(35)	GATAACACTGCGGCCAACTTACTTCTGACAACGATCG GAGGACCGAAGGAGCTAACCGC
p36	6005(36)	GATCATTTATCTTTCCTGCGGAGAAG
p65	PRM9t-R(65)	ATTTTCAACATCGTATTTTCCGAAGCG
p66	PRM9t-F(66)	ACAGAAGACGGGAGACACTAGC
p71	PYK1t-F(71)	AAAAAGAATCATGATTGAATGAAGATATTATTTTTTT GAATTATA
p122	GAL7p » Ii4CL3/opt-F(122)	GATAAAAAAAAAACAGTTGAATATTCCCTCAAAAATGC AAAAGCAAAGTTCTAATTCTGACATC
p123	Ii4CL3/opt «ENO2t-R(123)	GCAGAAAAGACTAATAATTCTTAGTTAAAAGCACTTT AATTGACCAAACCGGTGGCAAG
p124	GAL7p » Ptr4CL3/opt-F(124)	GATAAAAAAAAAACAGTTGAATATTCCCTCAAAAATG GATGCCATCATGAATTCTCAAGAAG
p125	Ptr4CL3/opt «ENOTt-R(125)	CAGAAAAGACTAATAATTCTTAGTTAAAAGCACTTTA AATACCGGGAAGAGTTTCTCTCAAGTTTTTTC
p126	GAL7p » Ptr4CL5/opt-F(126)	GATAAAAAAAAAACAGTTGAATATTCCCTCAAAAATG GATACTATTACTAAACAAAAAGAAGAATTCATTTTCA G
p127	Ptr4CL5/opt «ENOTt-R(127)	CAGAAAAGACTAATAATTCTTAGTTAAAAGCACTTTA CTTTTGCAATCCACCAGCCAAC
p129	CPS1t-F(129)	GCGCAATGATTGAATAGTCAAAGA
p130	CPS1t-R(130)	ATTTGACACTTGATTTGACACTTCTTTTTTTTTTTA
p131	HIS5t-F(131)	ATAGATTAATTTAAACAGTATATGTACAGTTTTATAT ATATATATATATATATATAC
p132	HIS5t-R(132)	GTAACAATATCATGAGACCTTTTATAGAAGTGGC
p134	SPG5t-R(134)	GCTTATTTTCTGCCGAATTTTCATGAAG
p136	IDP1t-R(136)	GATGGTAATGATCCGAACCTTGGGG
p137	PRM5t-F(137)	AAACTTTTATGATATTTTGCAATATTTTTTTTAAGCAG TGG

p139	LSC2t-F(139)	GCTTCTCGAGAAAAACAAAAGAGTT
p140	LSC2t-R(140)	AAAATTAAAAAAAAAAAAAAAAAGAAATTTTTTCCAAAA GAG
p157	PYK1t-R(157)	GCATTTATGTACCCATGTATAACCTTCCAAG
p182	XII-1up 《PRM9t-R(182)	GCAACGCTTCGGAAAATACGATGTTGAAAATTATTTG AAAGAACCGAACCGATGCC
p185	XII-1dw-R(185)	CCGTATGTGATGATATACTAATAACACGGATAC
p200	XII-5up》...-F(200)	GCTAAGTTATATAAGGTGTTACACGCG
p201	...《XII-5dw-R(201)	CTGATGGTCTTAAACAGGCATTACGTG
p202	... 《GAL10/1p-R(202)	CCATCCAAAAAAAAAAGTAAGAATTTTTGAAAATTC
p203	XII-5up-JDF(203)	GGAGGAGACCGCTATAACCGG
p204	XII-5-JDR(204)	CTGCGATACCTTTTGTGATGGC
p205	XII-5up-F(205)	GCGAACTGCCGTACTCGATGC
p206	XII-5up-R(206)	CATAACAAGAAAATCGCGTGAACACC
p207	XII-5dw-F(207)	GGAGTTCACCACGTAATGCCTG
p208	XII-5dw-R(208)	GATAAGCGAATTTGGCTAAGAACGTTG
p222	GAL10/1p》...-F(222)	CCTCTATACTTTAACGTCAAGGAGAAAAAAC
p228	XI-3up-F(228)	GGCAATCTCTGCAATACATACAGGG
p229	XI-3up-R(229)	GAAATCAGACGCACGCTTGCC
p230	XI-3dw-F(230)	CCTTACGTGGATTGAGCCAGC
p231	XI-3dw-R(231)	GCAGGAGCCAATAGTAGTCGG
p232	XI-3up》...-F(232)	CGTTTTAGGATATTGACGCCAAGCG
p233	...《XI-3dw-R(233)	AATAATGATCTGTATTGCTGGCTCAATCC
p234	liPLR1-JDF(234)	GGACAAGGAAATCCCACACCAAG
p236	AtPPR-JDF(236)	CACATCTACTACGAGGGATGCTTG
p248	XII-1 《GAL7p-R(248)	GCATATTTTCAAGAAGGATAGTAAGCTGGCAAATATT TGAAAGAACCGAACCGATGCC
p467	ENO2t CPS1t-R(467)	》GTGATATGCATATGGGAGATGGAGATGATACCTATTT GACACTTGATTTGACACTTCTTTTTTTTTTTA
p469	HIS5t 《XII-1dw-R(469)	GTATGGAACCTCCTAAGCATCGCAAGTCAGGGGTAAC AATATCATGAGACCTTTTATAGAAGTGGCG
p470	XII-1dw-F(470)	CCCTGACTTGCGATGCTTAGG
p472	CPS1t ScADH6-R(472)	》TAAAAAAAAAAAAATCTTTGACTATTCAATCATTGCGC TTAgtctgaaaattctttgtcgtagccgac
p473	ScADH6 《GAL10/1p-F(473)	CAAAAAAAAAAGTAAGAATTTTTGAAAATTCAATATAA CAAAtgtcttatcctgagaaattgaaggtatcgc
p475	HIS5t 《XII-5dw-R(475)	GATGGTCTTAAACAGGCATTACGTGGTGAACCTCCGTA ACAATATCATGAGACCTTTTATAGAAGTGGCG
p486	PGK1p-F(486)	ACGCACAGATATTATAACATCTGCACAATAG
p487	PGK1p-R(487)	TTTGTTATATTTGTTGTAAAAAGTAGATAATTACTTCC TTGATG
p490	PYK1t XII-3dw-F(490)	》CTAACTTGGAAGGTTATACATGGGTACATAAATGCGG TGTGATAGGCTCTAGGAACG

p491	XII-3dw-R(491)	gttacCAACGCATTTACAAACCACGG
p492	XII-3up 《PGK1p-R(492)	CAAATGCCTATTGTGCAGATGTTATAATATCTGTGCG TCCCATAATTTCAACCATCCTTAGCTTCC
p493	XII-3up-F(493)	GAAACTAACCCGATGGGACAATTACTG
p511	PGK1p URA3-F(511)	GAAGTAATTATCTACTTTTTTACAACAAATATAACAAA atggagggcacagttaagcc
p512	URA3 《PYK1t-R(512)	CAAAAAAATAATATCTTCATTCAATCATGATTCTTTTT AAGCTTtagtttgctggccgcatcttc
p515	MET15-F(515)	atgccatctcatttcgatactgttcaac
p516	MET15up-KOR(516)	ggaggaaacagccaaagcagc
p517	MET15up MET15dw-KOF(517)	ctttagaaggtggtgctgctgctttggctgttctccgattggtggtcatggtactactatc g
p518	MET15dw-KOR(518)	ctaactcaatgcatttccaccgtgc
p526	LEU2up-KOR(526)	ctctgacaacaacgaagtcagtacc
p527	LEU2up LEU2dw-KOF(527)	caatttgctaaaggtactgacttcgttggtgcagaggttgtacgaaccatgccacgg
p529	LEU2up-KOF(529)	gctgctatcgatgctacaggtg
p530	LEU2dw-KOR(530)	caccagttctgatacctgcatcc
p541	ADE2up-KOF(541)	gtgatgtgctaacgattgagattgagc
p542	ADE2up-KOR(542)	ctagcaggcgcataacataagtcac
p543	ADE2up ADE2dw-KOF(543)	caatatttgtagcttatgttatgcgctgctagggttggaatcatcatgggatcagac
p544	ADE2dw-KOR(544)	cttgaatcataagcgccaagcag
p561	eGFP《PYK1t-R(561)	CAAAAAAATAATATCTTCATTCAATCATGATTCTTTTT TTACTTGTACAGCTCGTCCATGCC
p577	XII-3up 《SPG5t-R(577)	CATAAAAACCTTCATGAAAATTCGGCAGAAAATAAGC CCCATAATTTCAACCATCCTTAGCTTCC
p578	SPG5t 《GAL10/1p-F(578)	GTAAGAATTTTTGAAAATTCAATATAACAAACAAAGA CGTTGTTTCATCGCGC
p579	IDP1t XII-3dw-F(579)	CAAGGTTCCCCAAGTTTCGGATCATTACCATCGGTGTG ATAGGCTCTAGGAACG
p581	SPG5t liDIR1-R(581)	CTTGGTAATAGCGCGATGAAACAACGTCTTTGTTAAT AACATTCATAGAGTTTAATATCCATCTTGACCC
p582	liDIR1 《GAL10/1p-F(582)	GTAAGAATTTTTGAAAATTCAATATAACAAAATGGTA AGCCAAATGAAACAATTTCTCCTC
p583	SPG5t liDIR2-R(583)	CTTGGTAATAGCGCGATGAAACAACGTCTTTGTTAGT AACATTCATATAGTTTAATATCCATCTTAACACGG
p584	liDIR2 《GAL10/1p-F(584)	GTAAGAATTTTTGAAAATTCAATATAACAAAATGGCA TCTCTTGTAGAGAAACAACCTC
p585	TsLAC3-JDR(585)	GGATGGTGGTAGAGGTCAACATGG
p587	TvLAC1-JDR(587)	GTTGGTTCCCTTCTGAAAGAATCCG
p588	liDIR1-JDR(588)	GAAGAACGATTACAATGCGTGTTTC

p589	liDIR2-JDR(589)	CTCTACGATGGCGACAATGTAGC
p616	GAL10/1p »	CTTTAACGTCAAGGAGAAAAAACTATACAAAATGGG
	trCgL-F(616)	TCCTTCTCTTAGACCAACTC
p617	GAL10/1p »	CTTTAACGTCAAGGAGAAAAAACTATACAAAATGGC
	trTsLAC3-F(617)	CATTGGTCCAGTCAC
p619	GAL10/1p »	ACTTTAACGTCAAGGAGAAAAAACTATACAAAATGG
	trTvLAC1-F(619)	GAATTGGTCCAGTCGC
p620	trliDIR1	GTAAGAATTTTTGAAAATTCAATATAACAAAATGACA
	《GAL10/1p-F(620)	AAACCATCTAAATCTCAATCAAAACC
p621	trliDIR2	GTAAGAATTTTTGAAAATTCAATATAACAAAATGTCC
	《GAL10/1p-F(621)	CAGAAAACATTGGATCAGAG
p660	XII-5up	TAAAAAAAAAAAAAGAAAGTGTCAAATCAAGTGTCAAAT
	《CPS1t-R(660)	CATAACAAGAAAATCGCGTGAACACC
p719	ADE2up	TATGCAACGCTTCGGAAAATACGATGTTGAAAATctagc
	《PRM9t-R(719)	aggcgcataacataagtcac
p720	PRM9t	CTATACTTTAACGTCAAGGAGAAAAAACTATACAAAA
	《GAL10/1p-F(720)	CAGAAGACGGGAGACACTAGC
p721	GAL10/1p »	CAAAAAAAAAAGTAAGAATTTTTGAAAATTCAATATAA
	mPlum/OPT-F(721)	CAAAATGGTTTCTAAAGGTGAAGAAGTTATTAAAG
p722	mPlum	CAAAAAAATAATATCTTCATTCAATCATGATTCTTTTT
	《PYK1t-R(722)	TTAAGCACCGGTAGAATGTCTACCTTC
p723	PYK1t »	CTTGGAAGGTTATACATGGGTACATAAATGCggttggaatc
	ADE2dw-F(723)	atcatgggatcagac
p726	GAL10/1p »	GTAAGAATTTTTGAAAATTCAATATAACAAAATGGTG
	eGFP-F(726)	AGCAAGGGCGAG
p727	MET15	CATTATGCAACGCTTCGGAAAATACGATGTTGAAAAT
	《PRM9t-R(727)	ggaggaaacagccaaagcagc
p728	PYK1t »	CTAACTTGGAAGGTTATACATGGGTACATAAATGCgga
	MET15dw-F(728)	ttggtggtcatggtactactatcg
p754	HIS5t »	GGCGCCACTTCTATAAAAGGTCTCATGATATTGTTAC
	XII5dw-F(754)	GGAGTTCACCACGTAATGCCTG
p767	trTsLAC3PO »	CTTGGTAGGGGTGGCGGTTTCGTCCAAACTGTAATCGA
	IDP1t-F(767)	ATTTACGTAGCCCAATCTACC
p796	SPG5t	CTATACTTTAACGTCAAGGAGAAAAAACTATACAAAC
	《GAL10/1p-R(796)	AAAGACGTTGTTTCATCGCGC
p855	GAL10/1p »	CTATACTTTAACGTCAAGGAGAAAAAACTATACAAAG
	LSC2t-F(855)	CTTCTCGAGAAAAACAAAAGAGTTAATAATAAAG
p1014	II1up-F(1014)	CAGTGGTGGAAAGGATTGGTAAGC
p1021	II-1dw-R(1021)	CCTTGAGAAGAACTTAGGGTATAATTTACACACC
p2001	ShPLR/opt	GTAAGAATTTTTGAAAATTCAATATAACAAAATGGCT
	《GAL10/1p-F(2001)	AAGTCTAGAGTTTTGATTGTTGG
	)	
p2002	PRM5t »	CTTAAAAAAAAATATTGCAAAATATCATAAAAGTTTTT
	ShPLR/opt-R(2002)	ACAAGTATCTCTTCAAGTATTCAGAAACAG

p2003	ShPLR-JDF(2003)	GTTTGTCCCATGGTCATCAAGC
p2004	ShPLR-JDR(2004)	CCTTCAACCAAATGAGCACCTTG
p2005	liPLR1-JDR(2005)	CTGGCCTCGATCAATCTGGC
p2006	AtPPR-JDR(2006)	GGCACCCAACCTCTTGAAAG
p2007	trLiDIR1-F-EcoRI(2007)	CGGAATTCGCCACCATGACAAAACCATCTAAATCTCAATCAAAAC
p2008	trLiDIR1-R-NotI(2008)	ATTTGCGGCCGCATGATGATGATGATGATGATAACATTCATAGAGTTTAATATCCATCTTG
p2009	trLiDIR2-F-EcoRI(2009)	CGGAATTCGCCACCATGTCCCAGAAAACATTGGATC
p2010	trLiDIR2-R-NotI(2010)	ATTTGCGGCCGCATGATGATGATGATGATGGTAACATTCATATAGTTTAATATCCATCTTAACACG
p2011	trAtDIR6-F-EcoRI(2011)	CGGAATTCGCCACCATGTTCCGTAAAACACTATTGATCAAAAAAAC
p2012	AtDIR6-F-EcoRI(2012)	CGGAATTCGCCACCATGGCTTTTTTGGTTGAAAAACAATTG
p2013	trAtDIR6-R-NotI(2013)	ATTTGCGGCCGCATGATGATGATGATGATGATAACATTCATACAATTTAATATCCATTTTAACTCTG
p2014	trFiDIR1-F-EcoRI(2014)	CGGAATTCGCCACCATGTTGTTTTTGTGTTTTTTGACTTCTACTTC
p2015	trFiDIR1-R-NotI(2015)	ATTTGCGGCCGCATGATGATGATGATGATGCCAACATTCATACAAATTAATATCAACTCTC
p2016	JDF-AOX1(2016)	GACTGGTTCCAATTGACAAGC
p2017	JDR-AOX1(2017)	GCAAATGGCATTCTGACATCC
p2018	GAL10-F(2018)	GATAATGGGGCTCTTTACATTTCAC
p2019	ADH1-R(2019)	ATAACTTATTTAATAATAAAAAATCATAAATCATAAGAAATTCGC
p2020	trLiDIR1-R-NotI-T(2020)	ATAAGAATGCGGCCGCTTAATGATGATGATGATGATGATAACATTCATAGAGTTTAATATCCATCTTG
p2021	trLiDIR2-R-NotI-T(2021)	ATAAGAATGCGGCCGCTTAATGATGATGATGATGATGATGTAACATTCATATAGTTTAATATCCATCTTAACACG
p2022	trAtDIR6-R-NotI-T(2022)	ATAAGAATGCGGCCGCTTAATGATGATGATGATGATGATGATAACATTCATACAATTTAATATCCATTTTAACTCTG
p2023	trFiDIR1-R-NotI-T(2023)	ATAAGAATGCGGCCGCTTAATGATGATGATGATGATGATGCCAACATTCATACAAATTAATATCAACTCTC
p2024	JDF-T7(2024)	AGCAGCTGTAATACGACTCACTATAGG
p2025	JDR-CYC1(2025)	CCTAGACTTCAGGTTGTCTAACTCCTTC
p2026	GAL1-10p » liUGT71B2-F (2026)	TACTTTAACGTCAAGGAGAAAAAACTATACAAAATGAAACAGGAGCTTGTTTTTCATACC
p2027	liUGT71B2 《LSC2t-R (2027)	TATTATTAACCTTTTTGTTTTTCTCGAGAAGCTCAAGAGATATTCGAAGTGACATCTTCAATG
p2028	liUGT71B2-JDF(2028)	GAGGAGATAGAGCGGGGGATC
p2029	GAL1-10p »	ATACTTTAACGTCAAGGAGAAAAAACTATACAAAAT

	IiUGT71B5a-F (2029)	GAAGATCGAGCTCGTGTTTCATAC
p2030	IiUGT71B5a 《LSC2t-R (2030)	TTTATTATTAAGTCTTTTGTCTCTCGAGAAGCCTAG ACCACAACATTCTCGATCACG
p2031	IiUGT71B5a-JDF(20 31)	GAACTCGATGCTTGAGAGCTTG
p2032	GAL1-10p 》 IiUGT71B5b-F (2032)	TATACTTTAACGTCAAGGAGAAAAAACTATACAAAAT GAAGATCGAGCTTGTGTTTCATG
p2033	IiUGT71B5b 《LSC2t-R (2033)	CTTTATTATTAAGTCTTTTGTCTCTCGAGAAGCTTA AGCCGCAACATTCTCGACC
p2034	IiUGT71B5b-JDF(20 34)	GGTAAATGCGTTCGAGATGGTG
p2035	THR4-up-F(2035)	CACAGCAAAACTACGCGAAATCAC
p2036	THR4-up 《THR4-dw-R(2036)	TTTGATGGTTCCTTACTCTCGCAATCATGATTCTGGTG TGAGGGATGGTGGC
p2037	THR4-dw-F(2037)	GAATCATGATTGCGAGAGTAAGGAACC
p2038	THR4-dw-R(2038)	GAAAGGAAACGGTGATACGGTG
p2039	ARG4-up-F(2039)	TCTTTAGTTACTGAAGAGTACGTGAGCG
p2040	ARG4-up-R(2040)	GTTTGCCTTAGTCTTGTTATATAGTTACCTGC
p2041	ARG4-up 》 ARG4-dw-F(2041)	AAAGCAGGTAAGTATATAACAAGACTAAGGCAAACC AGATGGCGACGTTATGCG
p2042	ARG4-dw-R(2042)	AAGCTTGGAATCCTGCAGATTGG
p2043	CYS4-up-F(2043)	CCCACCAGAGCTTATCAATGGC
p2044	CYS4-up 《CYS4-dw-R(2044)	CTATGTTTGCTTTTATTTGAAGCGTGGGTCTTATATG TCCTTTGAGCAAGTGGCC
p2045	CYS4-dw-F(2045)	ATAAGAACCCACGCTTCAAATAAAAGC
p2046	CYS4-dw-R(2046)	TGTCAAGAAATGACGGCCTGTTCTTC
p2047	SER1-up-F(2047)	CTTGAGGAAGGAGTGCTAATTCAGAATC
p2048	SER1-up-R(2048)	TGTTTCTTATCACTAATGGTTAATCGATGATTGATC
p2049	SER1-up 》 SER1-dw-F(2049)	AATCATCGATTAACCATTAGTGATAAGAAACATATCA GCGGAATATGCCTGTAATTTGG
p2050	SER1-dw-R(2050)	GCCCGTCCAAAAGTTTTCAATGAAAAG
p2051	SER2-up-F(2051)	TCCCTTAGCAAGGCAATTTCTTAGAATATC
p2052	SER2-up-R(2052)	TTTTTACAGCTGTCGTGCTTAATGTCTATG
p2053	SER2-up 》 SER2-dw-F(2053)	CATAGACATTAAGCACGACAGCTGTAAAACTGGTA AACATGATGTACTTTACGTAGCG
p2054	SER2-dw-R(2054)	GCTGACAAGAGAATAACGAGGACC
p2055	PRO2-up-F(2055)	GGAGAATGGAGGTTTGCCAAGAG
p2056	PRO2-up 《PRO2-dw-R(2056)	TACACGTCTTCATACATGGAAGTTAGCTTTATCCCTT TATATTGGTTGCCTGTGCTCC
p2057	PRO2-dw-F(2057)	GGATAAAGCTAAGTTCCATGTATGAAGGAC
p2058	PRO2-dw-R(2058)	GCTATTACTGTAGCCGTTATGATTGGAC
p2059	ILV1-up-F(2059)	CCTTCCACATATCGTCCAATTCTGC

p2060	ILV1-up 《ILV1-dw-R(2060)	GTTGTTGCGTAAATTTATAAAAGTAAATTGTCGGTTTG GCTTGTAGCACTCACACAAG
p2061	ILV1-dw-F(2061)	AACCGACAATTTACTTTATAAATTTACGCAACAAC
p2062	ILV1-dw-R(2062)	CAGCCATTGGAACAACCCAACC
p2063	LYS1-up-F(2063)	CAGGTATTGTGGACACAGATATGCAAG
p2064	LYS1-up-R(2064)	TTTTGCGGTTGTGTGAAAAATAAAGCG
p2065	LYS1-up LYS1-dw-F(2065)	》ACGAAAACGCTTTATTTTTTCACACAACCGCAAAAGCG CTCGTGTTAAAAGATCTTCAAG
p2066	LYS1-dw-R(2066)	GACAGTATTGTGGAGCAGTCAGC
p2067	LYS2-up-F(2067)	TTCGATTTACAGCGGACGG
p2068	LYS2-up-R(2068)	CACTGAAATTCCAGGAAAGGTAATAAACTCA
p2069	LYS2-up LYS2-dw-F(2069)	》GAGTTTATTACCTTTCCTGGAATTTTCAGTGGGTTGAGC ATTACGTATGATATGTCCATG
p2070	LYS2-dw-R(2070)	AAACAGTGAAGCTTCAGGGTAGTATG
p2071	gRNA-ARG4-1F (2071)	AAACTTCTCCGCAGTGAAAGATAAATGATCGTATGAT TATAAGATGTATAGTTTTAGAGCTAGAAATAG
p2072	gRNA-ARG4-1R (2072)	AAACTTCTCCGCAGTGAAAGATAAATGATCGTAAAGA TGCATCAAAGGATGTTTTAGAGCTAGAAATAG
p2073	gRNA-ARG4-2F (2073)	AAACTTCTCCGCAGTGAAAGATAAATGATCAACCTAT TAGATGGTCTCATGTTTTAGAGCTAGAAATAG
p2074	gRNA-ARG4-2R (2074)	AAACTTCTCCGCAGTGAAAGATAAATGATCTAAGACA TCTATCTCACCTTGTTTTAGAGCTAGAAATAG
p2075	gRNA-CYS4-1F (2075)	AAACTTCTCCGCAGTGAAAGATAAATGATCCCAAATT CGTCGATGACGAAGTTTTAGAGCTAGAAATAG
p2076	gRNA-CYS4-1R (2076)	AAACTTCTCCGCAGTGAAAGATAAATGATCCATCTTC AGTCAGTTCAGGGGTTTTAGAGCTAGAAATAG
p2077	gRNA-CYS4-2F (2077)	AAACTTCTCCGCAGTGAAAGATAAATGATCGGTATCG GTCTAGCTTTAATGTTTTAGAGCTAGAAATAG
p2078	gRNA-CYS4-2R (2078)	AAACTTCTCCGCAGTGAAAGATAAATGATCTCGATCA GAGTAGATCTGGAGTTTTAGAGCTAGAAATAG
p2079	gRNA-ILV1-1F (2079)	AAACTTCTCCGCAGTGAAAGATAAATGATCGGCGGTG GTGGTTTAATTGCGTTTTAGAGCTAGAAATAG
p2080	gRNA-ILV1-1R (2080)	AAACTTCTCCGCAGTGAAAGATAAATGATCGACAGCA CCGATCTTATTAGGTTTTAGAGCTAGAAATAG
p2081	gRNA-ILV1-2F (2081)	AAACTTCTCCGCAGTGAAAGATAAATGATCGGGTCTC AAGTCGTCTATAGTTTTAGAGCTAGAAATAG
p2082	gRNA-ILV1-2R (2082)	AAACTTCTCCGCAGTGAAAGATAAATGATCACAGGCA TAACGATAGTAGCGTTTTAGAGCTAGAAATAG
p2083	gRNA-LYS1-1F (2083)	AAACTTCTCCGCAGTGAAAGATAAATGATCGCGCTAG GAAGATGTGGTTCGTTTTAGAGCTAGAAATAG
p2084	gRNA-LYS1-1R (2084)	AAACTTCTCCGCAGTGAAAGATAAATGATCGGTTGGC TTTCTGGCTCCGGGTTTTAGAGCTAGAAATAG
p2085	gRNA-LYS1-2F (2085)	AAACTTCTCCGCAGTGAAAGATAAATGATCGCTACAA AGACCAAGCTGGGGTTTTAGAGCTAGAAATAG

p2086	gRNA-LYS1-2R (2086)	AAACTTCTCCGCAGTGAAAGATAAATGATCGGATGTG TTCGTGGACTAGAGTTTTAGAGCTAGAAATAG
p2087	gRNA-LYS2-1F (2087)	AAACTTCTCCGCAGTGAAAGATAAATGATCGTTGATT GGTCTAATGGAATGTTTTAGAGCTAGAAATAG
p2088	gRNA-LYS2-1R (2088)	AAACTTCTCCGCAGTGAAAGATAAATGATCGTCTTTC TTTAAAGATGCCAGTTTTAGAGCTAGAAATAG
p2089	gRNA-LYS2-2F (2089)	AAACTTCTCCGCAGTGAAAGATAAATGATCGCTTCAG GTGCTGGTGCTCGGTTTTAGAGCTAGAAATAG
p2090	gRNA-LYS2-2R (2090)	AAACTTCTCCGCAGTGAAAGATAAATGATCGCTTGAG TTAGTTCTATACTGTTTTAGAGCTAGAAATAG
p2091	gRNA-PRO2-1F (2091)	AAACTTCTCCGCAGTGAAAGATAAATGATCTGTGAAC ACG TTCAGAGAAAGTTTTAGAGCTAGAAATAG
p2092	gRNA-PRO2-1R (2092)	AAACTTCTCCGCAGTGAAAGATAAATGATCACCAGAC TTGATACTCAATGGTTTTAGAGCTAGAAATAG
p2093	gRNA-PRO2-2F (2093)	AAACTTCTCCGCAGTGAAAGATAAATGATCACTACAA AAATCCCGTGTTGTTTTAGAGCTAGAAATAG
p2094	gRNA-PRO2-2R (2094)	AAACTTCTCCGCAGTGAAAGATAAATGATCACTAAGG CATTGGAACCACGGTTTTAGAGCTAGAAATAG
p2095	gRNA-SER1-1F (2095)	AAACTTCTCCGCAGTGAAAGATAAATGATCGAAGTGT TCTACTTGCAAGGGTTTTAGAGCTAGAAATAG
p2096	gRNA-SER1-1R (2096)	AAACTTCTCCGCAGTGAAAGATAAATGATCAGATTTC TGAGACCAACTACGTTTTAGAGCTAGAAATAG
p2097	gRNA-SER1-2F (2097)	AAACTTCTCCGCAGTGAAAGATAAATGATCTGCATTC GACTATCCAACGGGTTTTAGAGCTAGAAATAG
p2098	gRNA-SER1-2R (2098)	AAACTTCTCCGCAGTGAAAGATAAATGATCAAGCGCC AGAAATATTCTTAGTTTTAGAGCTAGAAATAG
p2099	gRNA-SER2-1F (2099)	AAACTTCTCCGCAGTGAAAGATAAATGATCGCAAGTT GTATGGTGGTGAGTTTTAGAGCTAGAAATAG
p2100	gRNA-SER2-1R (2100)	AAACTTCTCCGCAGTGAAAGATAAATGATCGTCATTA CATAGTTGCAGAAGTTTTAGAGCTAGAAATAG
p2101	gRNA-SER2-2F (2101)	AAACTTCTCCGCAGTGAAAGATAAATGATCGAACGCG TTAAATTATTGCAGTTTTAGAGCTAGAAATAG
p2102	gRNA-SER2-2R (2102)	AAACTTCTCCGCAGTGAAAGATAAATGATCGAAATCA AGTTCATTGTTCAAGTTTTAGAGCTAGAAATAG
p2103	gRNA-THR4-1F (2103)	AAACTTCTCCGCAGTGAAAGATAAATGATCGATTCCA GATGCTGATCTAAGTTTTAGAGCTAGAAATAG
p2104	gRNA-THR4-1R (2104)	AAACTTCTCCGCAGTGAAAGATAAATGATCGTATAGT CTCATGATAGCAAGTTTTAGAGCTAGAAATAG
p2105	gRNA-THR4-2F (2105)	AAACTTCTCCGCAGTGAAAGATAAATGATCCGAGAA AAAGCAAATCACTGGTTTTAGAGCTAGAAATAG
p2106	gRNA-THR4-2R (2106)	AAACTTCTCCGCAGTGAAAGATAAATGATCGGCTGCA GAACCAGTGTCACGTTTTAGAGCTAGAAATAG
p2107	ARG4-JDF (2107)	CGACGACATGGACGAACATAATGG
p2108	ARG4-JDR (2108)	CATCCATCCGGAGTAATTTTCATGTG

p2109	CYS4-JDF (2109)	GACCTGGCAAGAATGGCTCTATG
p2110	CYS4-JDR (2110)	GGTGGGATTATTTGCTCTATCTTTACGG
p2111	ILV1-JDF (2111)	CGGAATCACCTGGAATTCGTTC
p2112	ILV1-JDR (2112)	TTCAGTGTGTTCCAGCGATCC
p2113	LYS1-JDF (2113)	TGATGTCAACGCTTGGAAGAAGC
p2114	LYS1-JDR (2114)	TTGCATGCAGGGAGGAACAAAG
p2115	LYS2-JDF (2115)	CAAGAGTTGTTTCCCTGCCAGAC
p2116	LYS2-JDR (2116)	GTCCTGTTTGTTCATATCGGGCTAAG
p2117	PRO2-JDF (2117)	CGACACTTCTAGTGAAGATCGAGAATG
p2118	PRO2-JDR (2118)	GACGCTGACAAGCTGGACAATC
p2119	SER1-JDF (2119)	CGTCCTTTGAAATTCTCGTCTTTCTTC
p2120	SER1-JDR (2120)	AGTTCTTCTCTGTTTAATTGCCACATTG
p2121	SER2-JDF (2121)	GCCGCATTTGTTGCCTGTG
p2122	SER2-JDR (2122)	AAAGTCTTGTTGAGCCCGTAAG
p2123	THR4-JDF (2123)	GTGCAAACCGTGAACAACTGG
p2124	THR4-JDR (2124)	CGATTATGCTCCTTCAGTTGCC
p2125	PRM5t 《 GAL1-10p (2125)	AAAAGTAAGAATTTTTGAAAATTCAATATAACAAAAA ACTTTTATGATATTTTGCAATATTTTTTTTAAGCAGTG G
p2126	II-1up 《 PRM9t-R (2126)	TTATGCAACGCTTCGAAAATACGATGTTGAAAATCA GTTTTGGCCAACCTGCAC
p2127	PRM9t 《 IiUGT71B2-R (2127)	GTAAAGTTGTGTGCTAGTGTCTCCCGTCTTCTGTTCAA GAGATATTCGAAGTGACATCTTCAATG
p2128	GAL10-1p 《 IiUGT71B2-F (2128)	AAGTAAGAATTTTTGAAAATTCAATATAACAAAATGA AACAGGAGCTTGTTTTCATACC
p2129	LSC2t 《 II-1dw-F (2129)	TTTGGAAGAAAATTTCTTTTTTTTTTTTTTAATTTTCCAT TTATCCTTACATCGCTCGTATTTG
p2130	PRM9t 《 IiUGT71B5a-R (2130)	GTAAAGTTGTGTGCTAGTGTCTCCCGTCTTCTGTCTAG ACCACAACATTCTCGATCACG
p2131	GAL10-1p 《 IiUGT71B5a-F (2131)	AAAGTAAGAATTTTTGAAAATTCAATATAACAAAATG AAGATCGAGCTCGTGTTTCATAC
p2132	PRM9t 《 IiUGT71B5b-R (2132)	GGTAAAGTTGTGTGCTAGTGTCTCCCGTCTTCTGTTTA AGCCGCAACATTCTCGACC
p2133	GAL10-1p 《 IiUGT71B5a-F (2133)	AAAAGTAAGAATTTTTGAAAATTCAATATAACAAAAT GAAGATCGAGCTTGTTGTTTCATG
p2134	CPS1t 《 UGP1-R (2134)	AAAAAAAAAATCTTTGACTATTCAATCATTGCGCTCAA TGTTCCAAGATTTGCAAATTACCAG
p2135	UGP1 《 tHXT7p-F (2135)	AAAACAAAAAGTTTTTTTAATTTTAATCAAAAAATGT CCACTAAGAAGCACACCAAAAAC

p2136	TDH3p » PGM1-F (2136)	TTAGTTTCGAATAAACACACATAAAACAAACAAAATGT CACTTCTAATAGATTCTGTACCAACAG
p2137	PGM1 « HIS5t-R (2137)	ATAAACTGTACATATACTGTTTAAATTAATCTATCTA TGTGCGGACTGTTGGTTCG
p2138	UGP1-JDR(2138)	GAGGTTGATCGAATCGAGCAATTTG
p2139	PGM1-JDF(2139)	GGGTGGAAGTTGTTGTTTGACTCC
p2140	UGP1 « GAL1-10p-F (2140)	AAGTAAGAATTTTTGAAAATTCAATATAACAAAATGT CCACTAAGAAGCACACCAAAAAC
p2141	GAL1-10p» PGM1-F (2141)	TACTTTAACGTCAAGGAGAAAAAACTATACAAAATGT CACTTCTAATAGATTCTGTACCAACAG
p2142	UGP1 « PGK1p-F (2142)	TAATTATCTACTTTTTACAACAAATATAACAAAATGT CCACTAAGAAGCACACCAAAAAC
p2143	up-HIS3-F1(2143)	GCGCTTCTAATAATGGCACCG
p2144	dw-HIS3-R1(2144)	GACAGCAGTTGGGTAGGCC
p2145	up-HIS3-F2(2145)	GGCAGCTCGTTACATAATCCG
p2146	dw-HIS3-R2(2146)	CACCAACAGGAGTCATATCACAGTC
p2147	PGM1-PLUS-F(2147)	CCGTTCAAACACAAGTGGCAG
p2148	PGM1-PLUS-R(214 8)	TGAAGTGTCAATTTCCCGCTGTATAC
p2149	UAS-TDH3p » eGFP-F(2149)	ACTTAGTTTCGAATAAACACACATAAAACAAACAAAAT GGTGAGCAAGGGCGAG
p2150	XII-3up « UAS-TDH3p-R (2150)	AAATCTGGAAGAGTAAAAAAGGAGTAGAAACATTCC CATAATTTCAACCATCCTTAGCTTCC
p2151	UAS-TDH3p » mPlum-F(2151)	ACTTAGTTTCGAATAAACACACATAAAACAAACAAAAT GGTTTCTAAAGGTGAAGAAGTTATTAAAG

Supplementary Data 2 Overview of DNA constructs used in this study.

Donor name	Donor constructs	Primer (F)	Primer (R)	Length (bp)
RC20b	<i>XII5up</i> -T _{CPSI} - <i>PtrCCoAOMT2</i> ^{opt} -P _{GAL10/1} -T _{HIS5} - <i>XII5dw</i>	p205	p208	2187
	<i>XII5up</i>	p205	p206	190
	<i>XII5up</i> >T _{CPSI} - <i>PtrCCoAOMT2</i> ^{opt} -P _{GAL10/1}	p200	p202	1021
	P _{GAL10/1} -T _{HIS5} < <i>XII5dw</i>	p7	p475	855
	<i>XII5dw</i>	p207	p208	241
RC20c	<i>XII5up</i> -T _{CPSI} - <i>PtrCCoAOMT2</i> ^{opt} -P _{GAL10/1} - <i>PtrAldOMT2</i> ^o p ^t -T _{HIS5} - <i>XII5dw</i>	p205	p208	3282
	<i>XII5up</i>	p205	p206	190
	<i>XII5up</i> >T _{CPSI} - <i>PtrCCoAOMT2</i> ^{opt} -P _{GAL10/1}	p200	p202	1021
	P _{GAL10/1} - <i>PtrAldOMT2</i> ^{opt} -T _{HIS5} < <i>XII5dw</i>	p7	p201	1953
	<i>XII5dw</i>	p207	p208	241
RC34c1	<i>XIIIup</i> -P _{GAL7} - <i>Ii4CL3</i> ^{opt} -T _{ENO2} -T _{CPSI} - <i>ScADH6</i> -P _{GAL10/1} - <i>AtCCR1</i> -T _{HIS5} - <i>XIII1dw</i>	p182	p185	6671
	<i>XIIIup</i> <P _{GAL7}	p182	p248	453
	P _{GAL7}	p13	p14	725
	P _{GAL7} > <i>Ii4CL3</i> ^{opt} <T _{ENO2}	p122	p123	1700
	T _{ENO2}	p11	p12	400
	T _{ENO2} >T _{CPSI}	p467	p129	224
	T _{CPSI} > <i>ScADH6</i> <P _{GAL10/1}	p472	p473	1161
	P _{GAL10/1} > <i>AtCCR1</i> ^{OPT} -T _{HIS5} < <i>XIII1dw</i>	p7	p469	1243
	<i>XIII1dw</i>	p470	p185	364
RC34c2	<i>XIIIup</i> -P _{GAL7} - <i>Ii4CL3</i> ^{opt} -T _{ENO2} -T _{CPSI} - <i>ScADH6</i> -P _{GAL10/1} - <i>PtrCCR2</i> ^{OPT} -T _{HIS5} - <i>XIII1dw</i>	p182	p185	6653
	<i>XIIIup</i> <P _{GAL7}	p182	p248	453
	P _{GAL7}	p13	p14	725
	P _{GAL7} > <i>Ii4CL3</i> ^{opt} <T _{ENO2}	p122	p123	1700
	T _{ENO2}	p11	p12	400
	T _{ENO2} >T _{CPSI}	p467	p129	224
	T _{CPSI} > <i>ScADH6</i> <P _{GAL10/1}	p472	p473	1161
	P _{GAL10/1} > <i>PtrCCR2</i> ^{OPT} -T _{HIS5} < <i>XIII1dw</i>	p7	p469	1225
	<i>XIII1dw</i>	p470	p185	364
RC34c3	<i>XIIIup</i> -P _{GAL7} - <i>Ptr4CL3</i> ^{opt} -T _{ENO2} -T _{CPSI} - <i>ScADH6</i> -P _{GAL10/1} - <i>AtCCR1</i> -T _{HIS5} - <i>XIII1dw</i>	p182	p185	6662
	<i>XIIIup</i> <P _{GAL7}	p182	p248	453
	P _{GAL7}	p13	p14	725
	P _{GAL7} > <i>Ptr4CL3</i> ^{opt} <T _{ENO2}	p124	p125	1690
	T _{ENO2}	p11	p12	400
	T _{ENO2} >T _{CPSI}	p467	p129	224
	T _{CPSI} > <i>ScADH6</i> <P _{GAL10/1}	p472	p473	1161

	$P_{GAL10/I} > AtCCR1^{OPT} - T_{HIS5} < XIII dw$	p7	p469	1243
	$XIII dw$	p470	p185	364
RC34c4	$XIII up - P_{GAL7} - Ptr4CL3^{opt} - T_{ENO2} - T_{CPSI} - ScADH6 - P_{GAL10/I} - PtrCCR2 - T_{HIS5} - XIII dw$	p182	p185	6644
	$XIII up < P_{GAL7}$	p182	p248	453
	P_{GAL7}	p13	p14	725
	$P_{GAL7} > Ptr4CL5^{opt} < T_{ENO2}$	p124	p125	1690
	T_{ENO2}	p11	p12	400
	$T_{ENO2} > T_{CPSI}$	p467	p129	224
	$T_{CPSI} > ScADH6 < P_{GAL10/I}$	p472	p473	1161
	$P_{GAL10/I} > PtrCCR2^{OPT} - T_{HIS5} < XIII dw$	p7	p469	1225
	$XIII dw$	p470	p185	364
RC34c5	$XIII up - P_{GAL7} - Ptr4CL5^{opt} - T_{ENO2} - T_{CPSI} - ScADH6 - P_{GAL10/I} - AtCCR1 - T_{HIS5} - XIII dw$	p182	p185	6671
	$XIII up < P_{GAL7}$	p182	p248	453
	P_{GAL7}	p13	p14	725
	$P_{GAL7} > Ptr4CL5^{opt} < T_{ENO2}$	p126	p127	1699
	T_{ENO2}	p11	p12	400
	$T_{ENO2} > T_{CPSI}$	p467	p129	224
	$T_{CPSI} > ScADH6 < P_{GAL10/I}$	p472	p473	1161
	$P_{GAL10/I} > AtCCR1^{OPT} - T_{HIS5} < XIII dw$	p7	p469	1243
	$XIII dw$	p470	p185	364
RC34c6	$XIII up - P_{GAL7} - Ptr4CL5^{opt} - T_{ENO2} - T_{CPSI} - ScADH6 - P_{GAL10/I} - PtrCCR2 - T_{HIS5} - XIII dw$	p182	p185	6653
	$XIII up < P_{GAL7}$	p182	p248	453
	P_{GAL7}	p13	p14	725
	$P_{GAL7} > Ptr4CL5^{opt} < T_{ENO2}$	p126	p127	1699
	T_{ENO2}	p11	p12	400
	$T_{ENO2} > T_{CPSI}$	p467	p129	224
	$T_{CPSI} > ScADH6 < P_{GAL10/I}$	p472	p473	1161
	$P_{GAL10/I} > PtrCCR2^{OPT} - T_{HIS5} < XIII dw$	p7	p469	1225
	$XIII dw$	p470	p185	364
RC52	$XII3 up - T_{SPG5} - P_{GAL10/I} - CgL^{OPT} - T_{IDP1} - XII3 dw$	p493	p491	3505
	$XII3 up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$P_{GAL10/I}$	p7	p8	668
	$P_{GAL10/I} > CgL^{OPT} - T_{IDP1} < XII3 dw$	p222	p136	1714
	$XII3 dw$	p579	p491	447
RC53	$XII3 up - T_{SPG5} - P_{GAL10/I} - TsLAC3^{OPT} - T_{IDP1} - XII3 dw$	p493	p491	3598
	$XII3 up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$P_{GAL10/I}$	p7	p8	668

	$P_{GAL10/I} > TsLAC3^{OPT} - T_{IDP1} < XII3dw$	p222	p136	1807
	$XII3dw$	p579	p491	447
RC55	$XII3up - T_{SPG5} - P_{GAL10/I} - TvLAC1^{OPT} - T_{IDP1} - XII3dw$	p493	p491	3586
	$XII3up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$P_{GAL10/I}$	p7	p8	668
	$P_{GAL10/I} > TvLAC1^{OPT} - T_{IDP1} < XII3dw$	p222	p136	1795
	$XII3dw$	p579	p491	447
RC52C	$XII3up - T_{SPG5} - P_{GAL10/I} - trCgL^{OPT} - T_{IDP1} - XII3dw$	p493	p491	3397
	$XII3up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$P_{GAL10/I}$	p7	p8	668
	$P_{GAL10/I} > trCgL^{OPT} - T_{IDP1} < XII3dw$	p616	p136	1598
	$XII3dw$	p579	p491	447
RC53C	$XII3up - T_{SPG5} - P_{GAL10/I} - trTsLAC3^{OPT} - T_{IDP1} - XII3dw$	p493	p491	3532
	$XII3up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$P_{GAL10/I}$	p7	p8	668
	$P_{GAL10/I} > trTsLAC3^{OPT} - T_{IDP1} < XII3dw$	p617	p136	1733
	$XII3dw$	p579	p491	447
RC55C	$XII3up - T_{SPG5} - P_{GAL10/I} - trTvLAC1^{OPT} - T_{IDP1} - XII3dw$	p493	p491	3526
	$XII3up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$P_{GAL10/I}$	p7	p8	668
	$P_{GAL10/I} > trTvLAC1^{OPT} - T_{IDP1} < XII3dw$	p619	p136	1728
	$XII3dw$	p579	p491	447
RC-DIR 1	$XII3up - T_{SPG5} - IiDIR1 - P_{GAL10/I} - TsLAC3^{OPT} - T_{IDP1} - XII3dw$	p493	p491	4147
	$XII3up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$T_{SPG5} > IiDIR1 < P_{GAL10/I}$	p581	p582	612
	$P_{GAL10/I}$	p7	p8	668
	$P_{GAL10/I} > TsLAC3^{OPT} - T_{IDP1} < XII3dw$	p617	p767	1768
	$XII3dw$	p579	p491	447
RC-DIR 2	$XII3up - T_{SPG5} - IiDIR2 - P_{GAL10/I} - TsLAC3^{OPT} - T_{IDP1} - XII3dw$	p493	p491	4162
	$XII3up < T_{SPG5}$	p493	p577	561
	$T_{SPG5} < P_{GAL10/I}$	p134	p578	244
	$T_{SPG5} > IiDIR2 < P_{GAL10/I}$	p583	p584	564
	$P_{GAL10/I}$	p7	p8	668
	$P_{GAL10/I} > TsLAC3^{OPT} - T_{IDP1} < XII3dw$	p617	p767	1768
	$XII3dw$	p579	p491	447

RC-trDI R1	<i>XII3up</i> -T _{SPG5} -tr <i>liDIR1</i> -P _{GAL10/1} -tr <i>TsLAC3</i> ^{OPT} -T _{IDP1} - <i>XII3dw</i>	p493	p491	3877
	<i>XII3up</i> <T _{SPG5}	p493	p577	561
	T _{SPG5} <P _{GAL10/1}	p134	p578	244
	T _{SPG5} >tr <i>liDIR1</i> <P _{GAL10/1}	p620	p582	480
	P _{GAL10/1}	p7	p8	668
	P _{GAL10/1} >tr <i>CgL</i> ^{OPT} -T _{IDP1} < <i>XII3dw</i>	p616	p767	1567
	<i>XII3dw</i>	p579	p491	447
RC-trDI R2	<i>XII3up</i> -T _{SPG5} -tr <i>liDIR2</i> -P _{GAL10/1} -tr <i>TsLAC3</i> ^{OPT} -T _{IDP1} - <i>XII3dw</i>	p493	p491	3829
	<i>XII3up</i> <T _{SPG5}	p493	p577	561
	T _{SPG5} <P _{GAL10/1}	p134	p578	244
	T _{SPG5} >tr <i>liDIR2</i> <P _{GAL10/1}	p621	p584	432
	P _{GAL10/1}	p7	p8	668
	P _{GAL10/1} >tr <i>CgL</i> ^{OPT} -T _{IDP1} < <i>XII3dw</i>	p616	p767	1567
	<i>XII3dw</i>	p579	p491	447
D2001	<i>XI3up</i> -T _{PRM5} -At <i>PRR</i> -Sc ^{OPT1} -P _{GAL10/1} -T _{LSC2} - <i>XI3dw</i>	p228	p231	2700
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> >T _{PRM5} -At <i>PRR</i> -Sc ^{OPT1} <P _{GAL10/1}	p232	p202	1171
	P _{GAL10/1}	p7	p8	676
	P _{GAL10/1} >T _{LSC2} < <i>XI3dw</i>	p855	p233	215
	<i>XI3dw</i>	p230	p231	330
D2002	<i>XI3up</i> -T _{PRM5} -Ii <i>PLR1</i> -Sc ^{OPT1} -P _{GAL10/1} -T _{LSC2} - <i>XI3dw</i>	p228	p231	2700
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> >T _{PRM5} -Ii <i>PLR1</i> -Sc ^{OPT1} <P _{GAL10/1}	p232	p202	1171
	P _{GAL10/1}	p7	p8	676
	P _{GAL10/1} >T _{LSC2} < <i>XI3dw</i>	p855	p233	215
	<i>XI3dw</i>	p230	p231	330
D2003	<i>XI3up</i> -T _{PRM5} -Sh <i>PLR</i> -Sc ^{OPT1} -P _{GAL10/1} -T _{LSC2} - <i>XI3dw</i>	p228	p231	2682
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> >T _{PRM5}	p232	p137	172
	T _{PRM5} >Sh <i>PLR</i> -Sc ^{OPT1} <P _{GAL10/1}	p2001	p2002	1002
	P _{GAL10/1}	p7	p8	676
	P _{GAL10/1} >T _{LSC2} < <i>XI3dw</i>	p855	p233	215
	<i>XI3dw</i>	p230	p231	330
D2004	<i>XI3up</i> -T _{PRM5} -Ii <i>PLR1</i> -Sc ^{OPT1} -P _{GAL10/1} -Ii <i>UGT71B2</i> -T _{LSC2} - <i>XI3dw</i>	p228	p231	4161
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> >T _{PRM5} -Ii <i>PLR1</i> -Sc ^{OPT1} <P _{GAL10/1}	p232	p202	1171
	P _{GAL10/1}	p7	p8	676
	P _{GAL10/1} >Ii <i>UGT71B2</i> <T _{LSC2}	p2026	p2027	1531
	T _{LSC2} < <i>XI3dw</i>	p139	p233	179

	<i>XI3dw</i>	p230	p231	330
D2005	<i>XI3up</i> - T_{PRM5} - <i>IiPLR1</i> -Sc ^{OPT1} - $P_{GAL10/1}$ - <i>IiUGT71B5a</i> - T_{LSC2} - <i>XI3dw</i>	p228	p231	4149
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> > T_{PRM5} - <i>IiPLR1</i> -Sc ^{OPT1} < $P_{GAL10/1}$	p232	p202	1171
	$P_{GAL10/1}$	p7	p8	676
	$P_{GAL10/1}$ > <i>IiUGT71B5a</i> < T_{LSC2}	p2029	p2030	1519
	T_{LSC2} < <i>XI3dw</i>	p139	p233	179
	<i>XI3dw</i>	p230	p231	330
D2006	<i>XI3up</i> - T_{PRM5} - <i>IiPLR1</i> -Sc ^{OPT1} - $P_{GAL10/1}$ - <i>IiUGT71B5b</i> - T_{LSC2} - <i>XI3dw</i>	p228	p231	4143
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> > T_{PRM5} - <i>IiPLR1</i> -Sc ^{OPT1} < $P_{GAL10/1}$	p232	p202	1171
	$P_{GAL10/1}$	p7	p8	676
	$P_{GAL10/1}$ > <i>IiUGT71B5b</i> < T_{LSC2}	p2032	p2033	1513
	T_{LSC2} < <i>XI3dw</i>	p139	p233	179
	<i>XI3dw</i>	p230	p231	330
D2007	<i>XI3up</i> - T_{PRM5} - $P_{GAL10/1}$ - <i>IiUGT71B2</i> - T_{LSC2} - <i>XI3dw</i>	p228	p231	3207
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> > T_{PRM5} < $P_{GAL10/1}$	p232	p2125	206
	$P_{GAL10/1}$	p7	p8	676
	$P_{GAL10/1}$ > <i>IiUGT71B2</i> < T_{LSC2}	p2026	p2027	1531
	T_{LSC2} < <i>XI3dw</i>	p139	p233	179
	<i>XI3dw</i>	p230	p231	330
D2008	<i>XI3up</i> - T_{PRM5} - $P_{GAL10/1}$ - <i>IiUGT71B5a</i> - T_{LSC2} - <i>XI3dw</i>	p228	p231	3195
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> > T_{PRM5} < $P_{GAL10/1}$	p232	p2125	206
	$P_{GAL10/1}$	p7	p8	676
	$P_{GAL10/1}$ > <i>IiUGT71B5a</i> < T_{LSC2}	p2029	p2030	1519
	T_{LSC2} < <i>XI3dw</i>	p139	p233	179
	<i>XI3dw</i>	p230	p231	330
D2009	<i>XI3up</i> - T_{PRM5} - $P_{GAL10/1}$ - <i>IiUGT71B5b</i> - T_{LSC2} - <i>XI3dw</i>	p228	p231	3189
	<i>XI3up</i>	p228	p229	464
	<i>XI3up</i> > T_{PRM5} < $P_{GAL10/1}$	p232	p2125	206
	$P_{GAL10/1}$	p7	p8	676
	$P_{GAL10/1}$ > <i>IiUGT71B5b</i> < T_{LSC2}	p2032	p2033	1513
	T_{LSC2} < <i>XI3dw</i>	p139	p233	179
	<i>XI3dw</i>	p230	p231	330
D2010	<i>THR4up</i> - <i>THR4dw</i>	p2035	p2038	1041
	<i>THR4</i> -up< <i>THR4</i> -dw	p2035	p2036	551
	<i>THR4</i> -dw	p2037	p2038	523
D2011	<i>ARG4up</i> - <i>ARG4dw</i>	p2039	p2042	995
	<i>ARG4</i> -up	p2039	p2040	491

	ARG4-up>ARG4-dw	p2041	p2042	539
D2012	<i>MET15up-MET15dw</i>	p515	p518	546
	MET15-up	p515	p516	255
	MET15-up>MET15-dw	p517	p518	329
D2013	<i>ADE2up-ADE2dw</i>	p541	p544	880
	ADE2-up	p541	p542	484
	ADE2-up>ADE2-dw	p543	p544	429
D2014	<i>SER2up-SER2dw</i>	p2051	p2054	979
	SER2-up	p2051	p2052	515
	SER2-up>SER2-dw	p2053	p2054	494
D2015	<i>PRO2up-PRO2dw</i>	p2055	p2058	1070
	PRO2-up<PRO2-dw	p2055	p2056	582
	PRO2-dw	p2057	p2058	523
D2016	<i>ILV1up-ILV1dw</i>	p2059	p2062	1058
	ILV1-up<ILV1-dw	p2059	p2060	573
	ILV1-dw	p2061	p2062	520
D2017	<i>LYS1up-LYS1dw</i>	p2063	p2066	1078
	LYS1-up	p2063	p2064	522
	LYS1-up>LYS1-dw	p2065	p2066	590
D2018	<i>LYS2up-LYS2dw</i>	p2067	p2070	1035
	LYS2-up	p2067	p2068	521
	LYS2-up>LYS2-dw	p2069	p2070	543
D2019	<i>IIIup-T_{PRM9}-IiUGT71B2-P_{GAL10/1}-IiUGT71B2-T_{LSC2}-III dw</i>	p1014	p1021	4521
	<i>IIIup<T_{PRM9}</i>	p1014	p2126	282
	<i>T_{PRM9}</i>	p65	p66	250
	<i>T_{PRM9}>IiUGT71B2<P_{GAL10/1}</i>	p2127	p2128	1528
	<i>P_{GAL10/1}</i>	p7	p8	676
	<i>P_{GAL10/1}>IiUGT71B2<T_{LSC2}</i>	p2026	p2027	1526
	<i>T_{LSC2}</i>	p139	p140	142
	<i>T_{LSC2}>III dw</i>	p2129	p1021	319
D2020	<i>IIIup-T_{PRM9}-IiUGT71B5a-P_{GAL10/1}-IiUGT71B5a-T_{LSC2}-III dw</i>	p1014	p1021	4497
	<i>IIIup<T_{PRM9}</i>	p1014	p2126	282
	<i>T_{PRM9}</i>	p65	p66	250
	<i>T_{PRM9}>IiUGT71B5a<P_{GAL10/1}</i>	p2130	p2131	1517
	<i>P_{GAL10/1}</i>	p7	p8	676
	<i>P_{GAL10/1}>IiUGT71B5a<T_{LSC2}</i>	p2029	p2030	1517
	<i>T_{LSC2}</i>	p139	p140	142
	<i>T_{LSC2}>III dw</i>	p2129	p1021	319
D2021	<i>IIIup-T_{PRM9}-IiUGT71B5b-P_{GAL10/1}-IiUGT71B5b-T_{LSC2}-III dw</i>	p1014	p1021	4485
	<i>IIIup<T_{PRM9}</i>	p1014	p2126	282

	T_{PRM9}	p65	p66	250
	$T_{PRM9}>IiUGT71B5b<P_{GAL10/I}$	p2132	p2133	1513
	$P_{GAL10/I}$	p7	p8	676
	$P_{GAL10/I}>IiUGT71B5b<T_{LSC2}$	p2032	p2033	1513
	T_{LSC2}	p139	p140	142
	$T_{LSC2}>III dw$	p2129	p1021	319
D2023	$XII5up-T_{CPSI}-ScUGPI-P_{GAL10/I}-ScPGM1-T_{HIS5}-XII5dw$	p205	p208	4656
	$XII5up$	p205	p206	190
	$XII5up>T_{CPSI}$	p129	p660	217
	$T_{CPSI}>ScUGPI<P_{GAL10/I}$	p2134	p2140	1566
	$P_{GAL10/I}$	p7	p8	676
	$P_{GAL10/I}>ScPGM1-T_{HIS5}$	p2141	p132	1891
	$T_{HIS5}>XII5dw$	p754	p208	278
D2027	$XII3up-T_{SPG5}-P_{GAL10/I}-eGFP-T_{PYK1}-XII3dw$	p493	p491	2951
	$XII3up<T_{SPG5}$	p493	p577	561
	$T_{SPG5}<P_{GAL10/I}$	p134	p796	249
	$P_{GAL10/I}$	p7	p8	676
	$P_{GAL10/I}>eGFP<T_{PYK1}$	p726	p561	789
	T_{PYK1}	p71	p157	401
	$T_{PYK1}>XII3dw$	p490	p491	451
D2028	$MET15up-TPRM9-P_{GAL10/I}-eGFP-T_{PYK1}-MET15dw$	p515	p518	2593
	$MET15up<T_{PRM9}$	p515	p727	292
	$T_{PRM9}<P_{GAL10/I}$	p65	p720	286
	$P_{GAL10/I}$	p7	p8	676
	$P_{GAL10/I}>eGFP<T_{PYK1}$	p726	p561	789
	T_{PYK1}	p71	p157	401
	$T_{PYK1}>MET15dw$	p728	p518	326
D2029	$ADE2up-TPRM9-P_{GAL10/I}-mPlum-T_{PYK1}-ADE2dw$	p541	p544	2888
	$ADE2up<T_{PRM9}$	p541	p719	518
	$T_{PRM9}<P_{GAL10/I}$	p65	p720	286
	$P_{GAL10/I}$	p7	p8	676
	$P_{GAL10/I}>mPlum<T_{PYK1}$	p721	p722	760
	T_{PYK1}	p71	p157	401
	$T_{PYK1}>ADE2dw$	p723	p544	427
D2030	$XII3up-P_{PGK1}-URA3-T_{PYK1}-XII3dw$	p493	p491	2695
	$XII3up<P_{PGK1}$	p493	p492	563
	$PPGK1$	p486	p487	286
	$P_{PGK1}>URA3<T_{PYK1}$	p511	p512	678
	T_{PYK1}	p71	p157	401
	$T_{PYK1}>XII3dw$	p490	p491	451
D2031	$LEU2up-LEU2dw$	p529	p530	443
	$LEU2-up$	p529	p526	265

	LEU2-up>LEU2-dw	p527	p530	214
D2032	<i>TRP1up-TRP1dw</i>	p587	p590	347
	TRP1-up	p587	p588	186
	TRP1-up>TRP1-dw	p589	p590	197
D2033	<i>XII3up-P_{UAS-TDH3}-eGFP-T_{PYK1}-XII3dw</i>	p493	p491	3462
	<i>XII3up<P_{UAS-TDH3}</i>	p493	p2150	559
	<i>P_{UAS-TDH3}</i>	p558	p559	1400
	<i>P_{UAS-TDH3}>eGFP<T_{PYK1}</i>	p2149	p561	793
	<i>T_{PYK1}</i>	p71	p157	401
	<i>T_{PYK1}>XII3dw</i>	p490	p491	451
D2034	<i>XII3up-P_{UAS-TDH3}-mPlum-T_{PYK1}-XII3dw</i>	p493	p491	3423
	<i>XII3up<P_{UAS-TDH3}</i>	p493	p2150	559
	<i>P_{UAS-TDH3}</i>	p558	p559	1400
	<i>P_{UAS-TDH3}>mPlum<T_{PYK1}</i>	p2151	p722	754
	<i>T_{PYK1}</i>	p71	p157	401
	<i>T_{PYK1}>XII3dw</i>	p490	p491	451

Supplementary Data 3 All genes modified in this study.

Gene name	GenBank ID	Optimized coding Sequence
<i>LmXFPK</i>	AY804190.1	ATGGCTGACTTTGACTCTAAGGAGTACCTGGAGCTGGTGGACAAGTGGTGGAGAGCCACCAACTACCTGTCTGCTGGCAT GATCTTCCTGAAGTCTAACCCACTGTTCTCTGTGACCAACACCCCAATCAAGGCTGAGGATGTGAAGGTGAAGCCAATTG GCCACTGGGGCACCATCTCTGGACAGACCTTCCTGTATGCCCATGCCAACAGACTGATCAACAAGTATGGCCTGAACATG TTCTATGTGGGAGGCCCTGGCCATGGAGGCCAAGTGATGGTGACCAATGCCTACCTGGATGGAGCCTACACAGAGGACT ACCCTGAGATCACCAAGACATTGAGGGGCATGTCTCACCTGTTCAAGAGATTCTCTTTCCCTGGAGGCATTGGCTCTCAC ATGACAGCTCAGACCCCTGGCTCTTTACATGAGGGAGGAGAGTTGGGCTACTCTCTGTCTCATGCCTTTGGAGCTGTGCT GGATAACCCTGACCAAGTGGCTTTTGCTGTTGTGGGGGATGGAGAGGCTGAGACTGGCCCATCTATGGCCTCTTGGCACT CTATCAAGTTCCTGAATGCCAAGAATGATGGAGCTGTGCTGCCTGTGCTGGACCTGAATGGCTTCAAGATCTCTAACCCA ACCATCTTCTCTAGAATGTCTGATGAGGAGATCACCAAGTTCTTTGAGGGCCTAGGCTACTCTCCAAGATTCATTGAGAA TGATGACATCCATGACTATGCCACCTACCATCAGCTGGCTGCCAACATCCTGGACCAAGCCATTGAGGACATCCAAGCCA TTCAGAATGATGCTAGAGAGAATGGCAAGTACCAAGATGGAGAGATCCCTGCCTGGCCTGTGATCATTGCTAGACTGCC AAAGGGCTGGGGAGGCCCAACCCATGATGCCTCTAACAACCCAATTGAGAACTCTTTCAGAGCCCACCAAGTGCCACTG CCACTGGAGCAGCATGACCTGGCCACCCTGCCTGAGTTTGAGGACTGGATGAACTCTTACAAGCCTGAGGAGCTGTTCAA TGCTGATGGCTCTCTGAAGGATGAGCTGAAGGCCATTGCCCCAAAGGGAGACAAGAGAATGTCTGCCAACCCAATCACC AATGGAGGAGCTGACAGATCTGACCTGAAGCTGCCAACTGGAGAGAGTTTGCCAATGACATCAATGATGACACAAGAG GCAAGGAGTTTGCTGACTCTAAGAGAAACATGGACATGGCCACCCTGTCTAACTACCTGGGAGCTGTGTCTCAGCTGAAC CCAACAAGATTCAGATTCTTTGGCCCTGATGAGACCATGTCTAACAGACTGTGGGGCCTGTTCAATGTGACCCCAAGACA GTGGATGGAGGAGATCAAGGAGCCACAAGATCAGCTGCTGTCTCCAAGTGGCAGAATCATTGACTCTCAGCTGTCTGAG CACCAAGCTGAGGGCTGGCTGGAGGGCTACACCCTGACTGGCAGAGTGGGCATCTTTGCCTCTTATGAGTCTTTCCCTGAG AGTGGTGGACACCATGGTGACACAGCACTTCAAGTGGCTGAGACATGCCTCTGAGCAAGCCTGGAGAAATGACTACCCA TCTCTGAACCTGATTGCCACCTCTACAGCCTTTCAGCAAGACCACAATGGCTACCCACCAAGACCCTGGCATGCTGAC CCACCTGGCTGAGAAGAAGTCTAACTTCATCAGAGAGTACCTGCCTGCTGATGGCAACTCTCTGCTGGCTGTGCAAGAGA

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<i>DdPEX4</i>	XP_644511.1	ATGGGAGTTACAATTATTGATACACCTGATCCTCAAGCAGTTTGTTACCTATTACATCAGCAGCAATCTTCATCGTCGCA ACACTTAACGCAGAAGCAGAAGCAGCAGAGAAGGTCCGAGGATGGTGTGCAGATATTGCAGGACTTACAAGATCAGTTG GAAAGAGGGTCCCTTCAGGAAACCTTTCATGTGTTTGTGGATTTCAGCAGCTCAGCATGGGATAGATTGTTTCGGCAGTCCT AGACCTGCATCACTTCATGATTTCCGAGAGTTTGGAGTTGAAGGAAGAAGAGCAGTTTCAACACCTGGAGATCTTCTTCT TCATATTAGAGCAGATCAAATGGATCTTTGTTTCGAGTTAGCAACACAACCTTATGTCAGCACTCGACGGTACTGTGACCG TAACCGACGAGGTGCAGGGTTTCCGCTATTTTGATATGCGTTCAATTATTGGATTTGTTGATGGTACCGAGAATCCTGTTG GAAGAAAGGCCGAGCATTTACCCCTCGTTGGAGATGAAGATCAACCTTTCAGCGGTGGATCATATGTTCTTGTTTCAGAAG TACTTGCATAACATGAAAGCATGGAACGAACTTCCTGTTGAAGCACAAGAAAGAGTTATTGGAAGAACAAAGTTGAGTG ATATTGAACTTGATGATTCAGTTAAACCTTCAAACCTCACATTCAGCACTTACAACAATTACAAAGGACGGAGAGGAGTT AAGATCTTAAGAGATAACATGCCTTTCGGCCGTCCTGGAGCAGGAGAATTTGGAACATATTTTCATAGGGTATGCAAGATC ACCTGAACCTCTTGAACAAATGCTTGAGAATATGTTTGTGGAAAGCCACCCGGCAACTATGATAGACTTCTTGATTCTC CACCGCAGTTACAGGATCATTGTTCTTCGTACCATCAGCAGATCTTCTTGAAGAACTTGCAGAAAGAGGAGGAGGATCAG CAGCAGTTAAACTTTCACAAGCAAAGTCCAAACTCTGA
<i>PfPEX5</i>	ABA74996.1	

<i>LiDIR1</i>	/	Studied in the previous study ¹ .
<i>LiDIR2</i>	/	Studied in the previous study ¹ .
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<i>LiUGT71 B2</i>	MK704396.1	Not optimized
<i>LiUGT71 B5a</i>	MW051594	Not optimized
<i>LiUGT71 B5b</i>	MW051595	Not optimized
<i>ScPGM1</i>	NP_012795.1	ATGTCACTTCTAATAGATTCTGTACCAACAGTTGCTTATAAGGACCAAAAACCGGGTACTTCAGGTTTACGTAAGAAGAC CAAGGTTTTTCATGGATGAGCCTCATTATACTGAGAACTTCATTCAAGCAACAATGCAATCTATCCCTAATGGCTCAGAGG

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ScUGPI NP_012889.3

		TTTCAACACTGACAAGGATACGGAACACTTGATTAAGAAGTATTCCGCTAACAGAATCAGAATCAGATCTTTCAATCAAT CCAGGTTCCCAAGAGTCTACAAGGATTCTTTATTGCCTGTCCCCACCGAATACGATTCTCCACTGGATGCTTGGTATCCAC CAGGTCACGGTGATTTGTTTGAATCTTTACACGTATCTGGTGAACCTGGATGCCTTAATTGCCCAAGGAAGAGAAATATTA TTTGTCTTAACGGTGACAACCTGGGTGCTACCGTCGACTTAAAAATTTAAACCACATGATCGAGACTGGTGCCGAATA TATAATGGAATTGACTGATAAGACCAGAGCCGATGTAAAGGTGGTACTTTGATTTCTTACGATGGTCAAGTCCGTTTAT TGGAAGTCGCCCAAGTTCCAAAAGAACACATTGACGAATTCAAAAATATCAGAAAGTTTACCAACTTCAACACGAATAA CTTATGGATCAATCTGAAAGCAGTAAAGAGGTTGATCGAATCGAGCAATTTGGAGATGGAAATCATTCCAAACCAAAAA ACTATAACAAGAGACGGTCATGAAATTAATGTCTTACAATTAGAAACCGCTTGTGGTGCTGCTATCAGGCATTTTGATGG TGCTCACGGTGTTGTCTGTTCCAAGATCAAGATTCTTGCCTGTCAAGACCTGTTCCGATTTGTTGCTGGTTAAATCAGATCT ATTCCGTCTGGAACACGGTTCTTTGAAGTTAGACCCATCCCGTTTTGGTCCAAACCCATTAATCAAGTTGGGCTCGCATTT CAAAAAGGTTTCTGGTTTTAACGCAAGAATCCCTCACATCCCAAAAATCGTCGAGCTAGATCATTTGACCATCACTGGTA ACGTCTTTTTAGGTAAAGATGTCATTTGAGGGGTACTGTCATCATCGTTTGCTCCGACGGTCATAAAATCGATATTCCAA ACGGCTCCATATTGGAAAATGTTGTCGTTACTGGTAATTTGCAAATCTTGGAACATTGA ATGGTGAGCAAGGGCGAGGAGCTGTTACCGGGGTGGTGCCCATCCTGGTTCGAGCTGGACGGCGACGTAAACGGCCACA AGTTCAGCGTGTCCGGCGAGGGCGAGGGCGATGCCACCTACGGCAAGCTGACCCTGAAGTTCATCTGCACCACCGGCAA GCTGCCCCGTGCCCTGGCCCACCTCGTGACCACCCTGACCTACGGCGTGCAGTGCTTCAGCCGCTACCCCGACCACATGA AGCAGCACGACTTCTTCAAGTCCGCCATGCCCCGAAGGCTACGTCCAGGAGCGCACCATCTTCTTCAAGGACGACGGCAA CTACAAGACCCGCGCCGAGGTGAAGTTCGAGGGCGACACCCTGGTGAACCGCATCGAGCTGAAGGGCATCGACTTCAAG <i>eGFP</i> ABF13214.1 GAGGACGGCAACATCCTGGGGCACAAGCTGGAGTACAACCTACAACAGCCACAACGTCTATATCATGGCCGACAAGCAGA AGAACGGCATCAAGGTGAACCTCAAGATCCGCCACAACATCGAGGACGGCAGCGTGCAGCTCGCCGACCACTACCAGCA GAACACCCCCATCGGCGACGGCCCCGTGCTGCTGCCCCGACAACCACTACCTGAGCACCCAGTCCGCCCTGAGCAAAGAC CCCAACGAGAAGCGCGATCACATGGTCCTGCTGGAGTTCGTGACCGCCGCCGGGATCACTCTCGGCATGGACGAGCTGT ACAAGTAA ATGGTTTCTAAAGGTGAAGAAGTTATTAAAGAATTTATGAGATTTAAAGAACATATGGAAGGTTCTGTTAATGGTCATGA <i>mPLUM</i> AAV65487.1 ATTTGAAATTGAAGGTGAAGGTGAAGGTAGACCATATGAAGGTACCCAAACCGCTAGATTGAAAGTTACCAAAGGTGGT CCATTGCCATTTGCTTGGGATATTTTGTCTCCACAAATTATGTATGGTTCTAAAGCTTATGTAAACATCCAGCTGATATT
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CCAGATTATTTGAAATTGTCTTTTCCAGAAGGTTTTAAATGGGAAAGAGTTATGAATTTGAAGATGGTGGTGTGTTACC
GTTACCCAAGATTCTTCTTTGCAAGATGGTGAATTTATTTATAAAGTTAAAGTTAGAGGTACCAATTTTCCATCTGATGGT
CCAGTTATGCAAAAAAAAAACCATGGGTTGGGAAGCTTCTTCTGAAAGAATGTATCCAGAAGATGGTGCTTTGAAAGGTG
AAATGAAAATGAGATTGAGATTGAAAGATGGTGGTCATTATGATGCTGAAGTTAAAACCACCTATATGGCTAAAAAACC
AGTTCAATTGCCAGGGGCTTATAAAACCGATATAAAATTGGATATTACCTCTCACAATGAAGATTATACCATTGTTGAAC
AATATGAAAGAGCTGAAGGTAGACATTCTACCGGTGCTTAA

Supplementary Data 4 Homology sequences for integration at selected chromosomal loci.

Chromosomal loci	Sequence (5'-3')	gRNA1 (20bp, 5'-3')	gRNA2 (20bp, 5'-3')
<i>XI5</i>	GCGGAGAAGTCGTTGATAGCATTTCCGAAGGCTTTTCCACATTGACTGCAGTATCTAAAAGAGCTC CAGCAGCGGTCTTAGTAGTTCCTGTGCTTGCCGCTTTGCAGTATACAGGGACATTGGGAACTACGG AGGAAAAATCGGAATGCTCTGAGCTCTTCTCAAAACCAGACGAACTCGTCTTATTTCTCAGTAAAT TACCCAACATATAAACTCTCCCTCTTCACCTTCTCTACAAGGCCACACACAAGACAGTTTTAACAG GCAATGGTACTGGAGGCTCTACCAATGGGGTTTAAGACGCTCCAAACACACGCTCTCCTTTTTT TCTTTATATATCGGTAGCAACGAAAGCTAGTCGCAGAACGTTACACACTAAAGCAGATCAATCAA	/	/
<i>XIII</i>	TCAATCCTGAGAACCTGCTTCGTTCAAACCATCCACTAGAAGAAACACGCACGTGTACCCAAAAA TAGAGACAAACAAACAGACAAAAATAACAATGATTCCTACCGACTAAAGTAAAACAACACTCAC GTAATAAAAAATCCTAGATACAACACTCACTTGTATTCTCTCTTTTGACCATCACTAAAGCTTCTC TCTTACTATATTCCTCAAATAAAAAAAAGTTGCAATGATTACTTACCAATGTGCCATAAACTCCGT GCACCA TGTTGAGCTCTGTCCTTCATGGACTTTTTTGGACCACTTCTTCTTGGACTTCTTACCACCAGCAAGAG CGGCAGCGGCTTTGGCAGCTTTAGACAATTGTTGCTTTGGAGGCATGTTATATTATGTTCTGAGAC GTAAGAAAGGGTGAAAATTGATGTTAGTGTCAAAAATTATATTACAAAATACGCAGAGATATTCT AGTTCCTTTGATGAATGAATCTTTCAGAAAAAAAAGTCAAAGCAAAAGCAAAATGGCCTGCAGAC TAAACTGTATGGTGGTCTTGGAATGATAAAGATCTGTTTAATAGATTTAGTAGATACAATAGCACA TCTCATTACCCAGTTATGATTGACGTCATTCTGAGTTACAATGATCTTAGCGACCTGTGCTCATTAT TTGCTCCACTAATTCTAATTTTCCTCGCCTTTCATATTTTCGTATCTTTATTCTATATCCTAAAATTTT TTTGGCAAATCCCAGATTTGGCTTTGATTTTGGCATCGGTTTCGGTTCTTTCAAATATCTTCTTCCCG TGAATCAACTGCACATACCTTAATAACTAGTTCAGTTTAGTGCTCTGTCTGAGTGACTGTAATAAT AAATTTTACAAGCCACTTCTCATGACATATATTGGTAAGTAACCTTCATCAATACTAATTAGTCTTTG CCGGTTACCCATCTGGCCCCTGACTTGCGATGCTTAGGAAGTTCCATACTCGCGGCTCTTCCCAAC AGTAGCACATCCGTGAAACTTCTGGCGCTATTCATTATGCAGTACCAGGACAAGAAGTTAAAAAA	CCACTTCTC ATGACATAT AT	CAATACTA ATTAGTCT TTGC

XII5

AAAGCTCTGTTACAAGTTCAATGGTGGTGAAGGATTGAAGTTATTATCCAGGAGGCACGGATGC
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ATTTTGTATA CTGTCCTG
T ATGT

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AGAGCTAAT	CTATTAAC
T	GAGC

	ACCAAAATCAGCTTGTAAGTTCTATCGTAATTATAAGGATAATTGACGCTTCTGTTGCTCTCTAGC CCATCTTGCTGTATCTTTTGTGGCTTGACTGAACAATTGGCCACTCCTAGTTCTTTTAATGTAATCA ATAACCCAGTCTTGTCCATAAAATTGTTTGATTGAGCCGTCTGGAAACATCGCTGCTATATCACCA ATCAATCCGACTGCTGCTCTTGAGGTAGCATCCTCACTGTACAGCTGAGGATCTTCTGCAACTT ATGCCATCTCATTTGATACTGTTCAACTACACGCCGGCCAAGAGAACCCTGGTGACAATGCTCAC AGATCCAGAGCTGTACCAATTTACGCCACCACTTCTTATGTTTTCGAAAACCTAAGCATGGTTCG CAATTGTTTGGTCTAGAAGTTCCAGGTTACGTCTATTCCCGTTTCCAAAACCAACCAGTAATGTTT TGGAAGAAAGAATTGCTGCTTTAGAAGGTGGTGCTGCTGCTTTGGCTGTTTCCTCCGGTCAAGCCG CTCAAACCCTTGCCATCCAAGGTTTGGCACACACTGGTGACAACATCGTTTCCACTTCTTACTTAT ACGGTGGTACTTATAACCAGTTCAAAATCTCGTTCAAAAGATTTGGTATCGAGGCTAGATTTGTTG AAGGTGACAATCCAGAAGAATTGAAAAGGTCTTTGATGAAAGAACCAAGGCTGTTTATTTGGAA ACCATTGGTAATCCAAAGTACAATGTTCCGGATTTTGAAAAAATTGTTGCAATTGCTCACAAACAC GGTATTCCAGTTGTCGTTGACAACACATTTGGTGCCGGTGGTTACTTCTGTCAGCCAATTAATAAC GGTGCTGATATTGTAACACATTCTGCTACCAAATGGATTGGTGGTCATGGTACTACTATCGGTGGT ATTATTGTTGACTCTGGTAAGTTCCCATGGAAGGACTACCCAGAAAAGTTCCCTCAATTCTCTCAA CCTGCCGAAGGATATCACGGTACTATCTACAATGAAGCCTACGGTAACTTGGCATAACATCGTTCAT GTTAGAACTGAACTATTAAGAGATTTGGGTCCATTGATGAACCCATTTGCCTCTTTCTTGCTACTAC AAGGTGTTGAAACATTATCTTTGAGAGCTGAAAGACACGGTGAAAATGCATTGAAGTTAGCCAAA TGGTTAGAACAATCCCCATACGTATCTTGGGTTTCATACCCTGGTTTAGCATCTCATTCTCATCATG AAAATGCTAAGAAGTATCTATCTAACGGTTTCGGTGGTGTCTTATCTTTCGGTGTAAAAGACTTAC CAAATGCCGACAAGGAACTGACCCATTCAAACCTTCTGGTGCTCAAGTTGTTGACAATTTAAAGC TTGCCTCTAACTTGGCCAATGTTGGTGATGCCAAGACCTTAGTCATTGCTCCATACTTCACTACCCA CAAACAATTAAATGACAAAGAAAAGTTGGCATCTGGTGTTACCAAGGACTTAATTCGTGTCTCTGT TGGTATCGAATTTATTGATGACATTATTGCAGACTTCCAGCAATCTTTTGAAACTGTTTTCGCTGGC CAAAAACCATGA		
<i>MET15</i>	ATTATTGTTGACTCTGGTAAGTTCCCATGGAAGGACTACCCAGAAAAGTTCCCTCAATTCTCTCAA CCTGCCGAAGGATATCACGGTACTATCTACAATGAAGCCTACGGTAACTTGGCATAACATCGTTCAT GTTAGAACTGAACTATTAAGAGATTTGGGTCCATTGATGAACCCATTTGCCTCTTTCTTGCTACTAC AAGGTGTTGAAACATTATCTTTGAGAGCTGAAAGACACGGTGAAAATGCATTGAAGTTAGCCAAA TGGTTAGAACAATCCCCATACGTATCTTGGGTTTCATACCCTGGTTTAGCATCTCATTCTCATCATG AAAATGCTAAGAAGTATCTATCTAACGGTTTCGGTGGTGTCTTATCTTTCGGTGTAAAAGACTTAC CAAATGCCGACAAGGAACTGACCCATTCAAACCTTCTGGTGCTCAAGTTGTTGACAATTTAAAGC TTGCCTCTAACTTGGCCAATGTTGGTGATGCCAAGACCTTAGTCATTGCTCCATACTTCACTACCCA CAAACAATTAAATGACAAAGAAAAGTTGGCATCTGGTGTTACCAAGGACTTAATTCGTGTCTCTGT TGGTATCGAATTTATTGATGACATTATTGCAGACTTCCAGCAATCTTTTGAAACTGTTTTCGCTGGC CAAAAACCATGA	TGCCATCCA AGGTTTGGC AC	GTTTCCAC TTCTTACT TATA
<i>ADE2</i>	ATGGATTCTAGAACAGTTGGTATATTAGGAGGGGGACAATTGGGACGTATGATTGTTGAGGCAGC	AAGAATTTC	GCCATTAT

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AAAACAAGTAA		

<i>THR4</i>	ATGCCTAACGCTTCCCAAGTTTACAGATCTACCAGATCCAGCTCTCCAAAGACCATCTCTTTTGAA GAGGCTATCATTCAAGGTCTGGCCACTGACGGTGGTCTTTTCATTCCACCAACTATTCCACAAGTG GACCAAGCCACTCTTTTCAATGATTGGTCAAAGCTCTCCTTCCAAGACTTAGCCTTTGCTATCATG AGACTATACATTGCCCAAGAAGAGATTCCAGATGCTGATCTAAAGGACTTGATCAAGAGATCTTA TTCTACTTTCCGTTCTGATGAAGTCACCCCTTGGTGCAAACGTCCTGGTGACAAGGAGAATTT GCACATTTTAGAATTATTCCACGGTCCTACCTACGCTTTCAAAGACGTTGCTTTACAATTTGTCGGT AATCTTTTTGAATACTTCTTACAAAGAACCAACGCCAATTTACCTGAAGGCGAGAAAAAGCAAAT CACTGTGGTTCGGTGCTACTTCCGGTGACACTGGTCTGCAGCCATCTACGGTTTAAGAGGCCAAAA GGACGTTTCCGTTTTTCATCTTATATCCAACCGGTAGAATTTCCCAATTCAAGAAGAACAAATGAC CACCGTTCAGATGAAAACGTCCAGACTTTGTCTGTTACCGGTACTTTGACAACGTGCAAGATAT CGTCAAAGCTATTTTCGGTGACAAAGAATTCAACTCTAAACACAACGTCGGTGCTGTTAACTCCAT CAACTGGGCAAGAATCTTGGCCCAAATGACCTATTACTTTTATTTCATTCTTCCAAGCCACCAACGG TAAGGACTCCAAGAAGGTCAAGTTCGTTGTGCCAAGTGGAAGTTCGGTGATATATTGGCCGGTT ATTTTGCCAAGAAAATGGGTTTGCCTATTGAAAACTGGCCATCGCTACCAATGAAAACGACATTT TGGACAGATTTTTGAAATCTGGTCTATACGAAAGATCAGACAAGGTTGCTGCTACTTTATCCCCAG CAATGGATATCTTAATCTCTTCTAACTTTGAAAGACTACTATGGTACCTAGCTCGTGAATACCTAG CTAATGGTGATGATTTGAAAGCCGGTGAAATCGTCAACAATTGGTTCCAGGAATTGAAGACCAAC GGTAAGTTCCAAGTTGACAAATCCATCATTGAAGGCGCATCAAAGGACTTTACATCAGAAAGAGT TTCCAATGAAGAAACATCTGAAACAATCAAGAAGATCTACGAATCATCTGTAAATCCAAAACATT ACATCTTAGATCCTCACACAGCTGTCGGTGTTTGCGCCACAGAAAGATTGATTGCAAAAGATAAT GACAAGTCCATCCAATACATTTCTCTATCTACCGCTACCCAGCTAAATTTGCCGATGCTGTAAAC AATGCATTGTCTGGATTTTCCAATTATTCATTTGAAAAGGATGTTTTGCCTGAGGAATTGAAGAAA TTATCCACATTAAAGAAGAAATTAATAATTCATCGAAAGAGCTGACGTTGAATTGGTCAAAAACGC TATTGAAGAAGAAGTCTGCTAAAATGAAATTATAA		
	ATGTCAGCTACTCTACTAAAGCAACCATTATGTACGGTTGTTCGGCAAGGTAAACAGTCCAAAGT GTCTGGATTGAACCTTTTGAGACTAAAGGCTCATTTGCACAGACAACACCTGTCACCTTCCTTGAT	GATTCCAGA TGCTGATCT AA	GTATAGTC TCATGATA GCAA
<i>ILV1</i>		GGCGGTGGT GGTTTAATT	GACAGCAC CGATCTTA

	AAAACTACACTCTGAATTGAAATTGGATGAGCTGCAAAGTGAATAACACCCCTGATTACGTCCGTTT AGTTTTAAGGTCCTCTGTATACGATGTTATTAATGAATCTCCAATCTCTCAAGGTGTAGGTTTGTCT TCCCGTCTAAACACGAATGTCATCTTGAAAAGAGAAGATCTATTGCCTGTTTTCTCTTTCAAGCTTC GTGGTGCCTATAACATGATTGCCAAGTTGGACGATTCTCAAAGAAACCAGGGTGTTATTGCCTGTT CAGCTGGGAATCATGCCCAAGGTGTGGCCTTTGCTGCTAAACACTTGAAAATACCTGCTACTATCG TTATGCCTGTTTGTACACCATCTATTAAGTATCAAAATGTCTCGAGATTAGGGTCTCAAGTCGTCCT ATATGGTAACGATTTTGACGAGGCTAAGGCTGAATGTGCCAAATTGGCTGAAGAGCGTGGCTTAA CGAACATTCTCCTTTTCGATCATCCTTATGTCATTGCGGGTCAAGGTACTGTAGCTATGGAAATCC TAAGACAAGTACGTACCGCTAATAAGATCGGTGCTGTCTTTGTTCCCGTCGGCGGTGGTGGTTTAA TTGCTGGTATTGGTGCTTATTTGAAAAGGGTTGCTCCTCATATCAAAATCATTGGTGTGAAACTT ACGATGCGGCCACTTTACATAATTCCTTGCAACGCAACCAGAGAACTCCTTTACCTGTGGTGGGTA CTTTTGCCGATGGTACGTCTGTGCGTATGATTGGTGAAGAAACATTTAGAGTCGCCCAACAAGTGG TTGATGAAGTTGTTCTTGTTAACTGACGAAATCTGTGCTGCAGTAAAGGATATTTTTGAAGATA CTAGAAGTATTGTAGAACCATCTGGTGCCCTTTCAGTAGCCGGTATGAAGAAATACATCTCTACCG TACATCCAGAAATTGACCACACTAAAAACACCTATGTTCCCATCCTTTCTGGTGCTAACATGAACT TTGATAGATTAAGATTTGTTTCCGAACGTGCTGTTCTTGGTGAAGGAAAGGAAGTCTTCATGTTAG TTACTTTACCCGACGTCCCTGGTGCGTTCAAGAAAATGCAAAGATCATCCACCCAAGATCTGTTA CTGAATTCTCTTACCGTTACAATGAACATCGTCATGAGTCCTCTAGTGAAGTGCCCAAGGCTTACA TTTACACTTCTTTCAGCGTCGTTGACAGAGAAAAGGAAATCAAGCAAGTTATGCAACAGTTGAAT GCTTTAGGTTTTGAAGCTGTGGATATCTCCGATAACGAATTGGCTAAATCTCATGGTAGATACTTG GTTGGTGGTGCTTCTAAGGTTCCCTAATGAAAGAATTATTTCAATTTGAATTCCTGAAAGACCAGGT GCCTTGACTAGGTTCTTGGAGGCCTAAGCGATTCTTGAATCTTACTTTATTCCATTATAGAAAC CATGGTGCCGATATCGGTAAGGTTTTAGCTGGTATTTCCGTTCTCCAAGGGGAAAACCTTAACCTTC CAAAAATTCTTGGAAGATTTAGGCTACACTTATCATGATGAAACTGATAACACTGTTTATCAAAAA TTCTTGAAATATTAA ATGTCAAAGTTTGTATCACCTGCATAGCTCATGGAGAAAATCTCCCAAAAGAAACCATCGACCA	GC	TTAG
SER2		GCAAGTTGT	GTCATTAC

PRO2

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ATGGTGGGT
GA

ATAGTTGC
AGAA

TGTGAACAC
GTTTCAGAGA
AA

ACCAGACT
TGATACTC
AATG

<i>ARG4</i>	AACGTTGTTGATTAACCCAAAATTCTCTAAGTGGTGGGAAGTTCTGGAAAACCTTAACCTTTGGAAGG CGGAGTGACTATCCACGCTACAAAAGATTTGAAAACCTGCGTATTTTGATAAACTGAATGAGTTAG GGAAATTGACAGAAGCAATTCAATGCAAAAACCGTTGATGCTGATGAGGAGCAAGATTTTGATAAG GAATTTTTATCCTTGGATTTGGCTGCCAAGTTTGTTACATCTACAGAATCGGCCATTCAACATATA AATACACACTCTTCGAGACATAACCGACGCTATTGTAACGGAAAATAAAGCAAACGCTGAAAAATT TATGAAGGGTGTGCGACTCCTCTGGTGTCTACTGGAATGCATCAACTAGATTTGCCGATGGTTTCAG GTACGGTTTTGGTGCTGAAGTGGGTATTTCTACCTCTAAGATTCACGCCCCTGGTCCAGTTGGCTT GGACGGTCTGGTGAGTTATCAATACCAAATAAGAGGTGACGGCCAGGTTGCTAGTGACTACCTTG GTGCTGGTGGTAACAAAGCTTTTGTTTACAAGGATTTAGATATAAAGACTGTGACATTATAA ATGTCAGACGGCACTCAAAAACCTATGGGGTGGGAGATTCACTGGTGAAACCGATCCTTTGATGCA TCTTTACAATGCCTCTCTTCCGTATGATTATAAGATGTATAAGGCAGATTTAGAAGGAACCTAAAGT ATACACAGCGGGCTTGCGAGAAGTTGGGTCTTCTAACGGAGACAGAATTGGCAAAGATCCATGAAG GTTTGGCTGAAATCAAAAAAGAATGGGACGCTGACAAATTTGTCCGTCATCCAAACGACGAGGAT ATCCATACTGCGAATGAAAGACGTCTTGGTGAACCTAATTGGCCGCGATATTGCTGGTAAAGTCCA CACCGGTAGATCCCGTAATGATCAAGTTGTTACCGATTTGAGAATATACTGTCGTGACATTGTCAA TGACACCCTCTTTCCAGCTCTAAAGGGCTTGGTTGAAGTTCTAATTAAGAGGGCCGAAGGTGAGAT AGATGTCCTTAATGCCAGGCTACACACATTTACAAAGGGGCACAACCTATTAGATGGTCTCATTGGTT GAGCTCTTATGCAACATACTTCACCGAAGATTACAAGAGACTGGGTCAAATACTACACAGATTGA ATCAATCACCACTGGGTGCAGGCGCTCTTGCTGGTCATCCTTACGGCATTGATAGAGAATTTTGG CTGAAGGTTTGGGTTTCAATAGTGTAATTGGTAACTCCTTGGTTGCTGTTTCTGATAGAGATTTTCT CGTGGAGTTGATGTTTTGGGGAACCTTTGTTTCAATGAACCATATTTCTCGTTTTGCTGAAGATTTGATT ATATATTGTACAGCAGAATTTGGTTTCATACAGTTGAGCGACGCCTATTCAACAGGTTCTTCTTTA ATGCCTCAGAAAAAGAATGCAGACTCGTTAGAGTTGTTAAGAGGTAAATCCGGTAGAGTGGTGG TGATCTGACAGGATTCTTGATGAGTTTGAAGGGTATCCCATCTACTTATGATAAAGACATGCAAGA AGACAAAGAGCCATTATTTGATTGCTTAACAACCTGTAGAGCACTCCATGCTGATTGCCACAGGTGT TATTTCTACCTTAACTGTAAATAAGGAAAAGATGGAAGCTGCTCTCACGATGGATATGCTAGCTAC	GTATGATTA TAAGATGTA TA	GTAAAGAT GCATCAAA GGAT
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<i>TRP1</i>	CGACTTGGCAGATTACTTGGTCAGAAAGGGTGTTCCATTGAGAGAGACTCATCACATATCTGGTGA		
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	GGTCAATGATTACGGCATTGATATCGTCCAACCTGCATGGAGATGAGTCGTGGCAAGAATACCAAG	GATTCAGAA	GTTTCGTA
<i>LYS2</i>	AGTTCCTCGGTTTGCCAGTTATTAAGAACTCGTATTTCCAAAAGACTGCAACATACTACTCAGTG	GCAGGTGGG	ATCAACCT
	CAGCTTCACAGAAACCTCATTGTTTATTCCCTTGTTTGATTGAGAAGCAGGTGGGACAGGTGAAC	AC	AAGG
	TTTTGGATTGGAACCTCGATTTCTGACTGGGTGGAAGGCAAGAGAGCCCCGAAAGCTTACATTTTA		
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	AAAAATGCTAAGAAATAG		
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	CTTTTTACGCCCACAACAAGAACCTTATACGAAACAAGCTACATATTCGTTACAGCTACCTCAGCT		
	CGATGTGCCTCATGATAGTTTTTCTAACAAATACGCTGTCGCTTTGAGTGTATGGGCTGCATTGAT		
	ATATAGAGTAACCGGTGACGATGATATTGTTCTTTATATTGCGAATAACAAAATCTTAAGATTCAA	ACTCAAGAT	GCGGAATG
<i>LYS2</i>	TATTCAACCAACGTGGTCATTTAATGAGCTGTATTCTACAATTAACAATGAGTTGAACAAGCTCAA	GATATTGGT	GATGAGTA
	TTCTATTGAGGCCAATTTTTCCTTTGACGAGCTAGCTGAAAAAATTCAAAGTTGCCAAGATCTGGA	AC	AGTA
	AAGGACCCCTCAGTTGTTCCGTTTGGCCTTTTGGAAAACCAAGATTTCAAATTAGACGAGTTCAA		
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	TATAACAGCTTACTGTATTCGAATGAAAGAGTAACCATTTGTTGCGGACCAATTTACTCAATATTTG		
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	CGTTGTTGTCAGAGAATTAGTGGGAGGTATTTACTTTGGTAAGAGAAAGGAAGACGATGGTGATG		
	GTGTCGCTTGGGATAGTGAACAATACACCGTTCCAGAAGTGCAAAGAATCACAAGAATGGCTGCT	ATTTGGTCCT	AAGATTAT
LEU2	TTCATGGCCCTACAACATGAGCCACCATTCCTATTTGGTCCTTGGATAAAGCTAATGTTTTGGCC	TGGATAAAG	GGAGAAA
	TCTTCAAGATTATGGAGAAAAACTGTGGAGGAAACCATCAAGAACGAATTCCTACATTGAAGGT	C	AACTG
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	GGGTTTGTGGCATCTGCGTCCTTGGCCTCTTTGCCAGACAAGAACACCGCATTTGGTTTGTACGA		
	ACCATGCCACGGTTCTGCTCCAGATTTGCCAAAGAATAAGGTCAACCCTATCGCCACTATCTTGTC		
	TGCTGCAATGATGTTGAAATTGTCATTGAACTTGCTGAAGAAGGTAAGGCCATTGAAGATGCAG		
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	GTCGGTGATGCTGTCGCCGAAGAAGTTAAGAAAATCCTTGCTTAA		
	GGTTAGTTACTTGCTCTATGCGTTTGCGCATCCTCTTTTTACTTTTTTTTTTCAGTAAAGCCTAAGC		
	ATAAATCGTTTTATACGTACGACACGTTCAACTTTTCTTGGTTAGTAGTGGCAATCTCTGCAATAC		
	ATACAGGGAGTCATGGTCTATCATCTTGTCCAATCAAAGAAGCATCGGTTTCAGATCGAGCAAAT	AATCCGGAA	TATGTTAC
XI3	GTAGGGAGAAAGGAAAGTAGAAATGCAGAGTGTGCTATATGTCCAATCTCGGTTTTGTAGTTTG	GTAGCGACG	GGATCTTG
	ATGTCATTAGAGATCTACCACCCAACCGGCTGCTTTCATGTGGAACAGAAAAGAAATCGGGGCGC	GG	CACG
	TTCCTCTTCTGTATTCCTTTAATTAACGTTTTTATTCAGCCATCTAACCATCATACCCCATACGGT		
	AACAAAACCTCTTCTAAGAAAAGAAGTCTCTGCTCCTCCGCCATCTTATTTTTATTCGCTGCGCGC		

III

GTTTATTGTCGCATCGCTAGCCAGCAAAAAGTTGGTTGCCTTTTTTTACCTAAAAAAGACACATCT
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CACTGTG

CGCCCATTT	ATGGATAC
AAAGGTTCA	ATGGCGTA
AC	GCTA

Engineering chromosomal locis related to strain RB218 have been studied in previous study².

Supplementary Data 5 Source data of Supplementary Fig. 1.

Supplementary Fig. 1a	Remaining titer <i>p</i> CA (mg l ⁻¹)			Remaining titer CaA (mg l ⁻¹)		
RB57	139.3	194.6	176.5	195.7	175.8	176.3

Supplementary Data 6 Source data of Supplementary Fig. 5.

Supplementary Fig. 5a		pinoresinol glucoside titer (mg l ⁻¹)		
RB218 ^{met15Δ} -XH7B1 ^{ade2Δ}	1.4	0.6	1.6	

Supplementary Fig. 5b		pinoresinol diglucoside titer (mg l ⁻¹)		
RB218 ^{met15Δ} -XH8B1 ^{ade2Δ}	0.6	0.4	0.5	

Supplementary References

1. Chen, R.B. et al. The ERF transcription factor LTF1 activates DIR1 to control stereoselective synthesis of antiviral lignans and stress defense in *Isatis indigotica* roots. *Acta Pharmaceutica Sinica B* **14**, 405-420 (2024).
2. Chen, R.B. et al. Engineering cofactor supply and recycling to drive phenolic acid biosynthesis in yeast. *Nature Chemical Biology* **18**, 520-529 (2022).