

**Table S4.** Summary of joint linkage mapping for 12 metabolites and first two principal compor

Trait	QTL	Marker	Chr	cM	DF	SS	MS	FValue
AA	m95	PZA0139	1	116.5	26	14.3387	0.5515	3.1964
AA	m200	PZA0010	2	38.6	26	16.1421	0.6209	3.5984
AA	m262	PZA0352	2	97.5	26	30.6849	1.1802	6.8403
AA	m376	PZD0002	3	80.8	26	12.175	0.4683	2.7141
AA	m395	PZA0374	3	100.6	26	11.7846	0.4533	2.627
AA	m493	PZA0027	4	80.6	26	14.3615	0.5524	3.2015
AA	m579	PZA0211	5	56.2	26	18.7965	0.7229	4.1902
AA	m648	PZA0345	5	91.9	26	10.9984	0.423	2.4518
AA	m677	PZA0083	5	132.6	26	16.698	0.6422	3.7224
AA	m703	PHM8909	6	18.6	26	17.8569	0.6868	3.9807
AA	m789	PZA0121	7	49.5	26	11.3966	0.4383	2.5406
AA	m816	PZA0272	7	81.2	26	16.2574	0.6253	3.6241
AA	m888	PZA0301	8	62.3	26	19.3376	0.7438	4.3108
AA	m924	PHM1562	8	88.5	26	13.1799	0.5069	2.9381
AA	m960	zb7.2	9	38.9	26	25.6848	0.9879	5.7257
AA	m1067	PHM1262	10	43.8	26	14.0668	0.541	3.1358
AA	m1091	PZA0360	10	75.4	26	11.2361	0.4322	2.5048
AA	m1105	PZA0006	10	93.7	26	12.6144	0.4852	2.812
Chla	m79	PZA0320	1	89.7	26	4927.59	189.523	3.0384
Chla	m216	PZA0137	2	59.9	26	4766.03	183.309	2.9387
Chla	m316	PHM4204	3	38.3	26	4099.7	157.681	2.5279
Chla	m411	PZA0314	3	127.7	26	9230.97	355.037	5.6918
Chla	m666	PZA0266	5	110.7	26	5608.44	215.709	3.4582
Chla	m968	PZB0111	9	41.8	26	5761.95	221.614	3.5528
Chla	m1106	PZA0252	10	101.9	26	5013.19	192.815	3.0911
Chlb	m73	PZA0275	1	87.9	26	113.644	4.3709	3.5191
Chlb	m87	PZA0353	1	99.3	26	103.678	3.9876	3.2105
Chlb	m166	PZA0123	1	196.8	18	122.272	6.7929	5.469
Chlb	m170	PZA0085	1	199.4	18	940.037	52.2243	42.0462
Chlb	m175	PHM7616	1	202.4	25	108.354	4.3342	3.4895
Chlb	m261	PZA0075	2	94.9	26	81.0851	3.1187	2.5109
Chlb	m589	PZA0153	5	58.3	26	85.6707	3.295	2.6529
Chlb	m818	PZA0226	7	92.2	19	185.352	9.7554	7.8541
Chlb	m824	PZA0222	7	112.2	23	152.625	6.6358	5.3426
Fruc	m304	PZA0209	3	15	26	1.1576	0.0445	3.2379
Fruc	m339	PZA0050	3	57.7	26	1.008	0.0388	2.8193
Fruc	m625	PZA0014	5	76.9	26	0.8326	0.032	2.3287
Fruc	m680	PZA0248	5	152.3	26	0.9	0.0346	2.5171
Fruc	m771	PHM1550	7	47.8	26	1.5823	0.0609	4.4255
Fruc	m959	PZA0305	9	34.5	26	0.8972	0.0345	2.5093
Fruc	m1035	PHM2828	10	21.3	26	0.9488	0.0365	2.6537

Fuma	m95	PZA0139	1	116.5	26	0.0453	0.0017	2.4192
Fuma	m192	PZA0208	2	18.3	26	0.0362	0.0014	1.9292
Fuma	m222	PZA0249	2	67.9	26	0.0343	0.0013	1.8295
Fuma	m276	PZA0207	2	115.3	26	0.0416	0.0016	2.2203
Fuma	m281	PZA0360	2	120.5	26	0.0452	0.0017	2.4102
Fuma	m425	PZA0031	3	145.1	26	0.0366	0.0014	1.9537
Fuma	m502	PZA0219	4	93.2	26	0.0568	0.0022	3.0321
Fuma	m559	PZB0009	5	30.2	26	0.0424	0.0016	2.2631
Fuma	m792	PZA0193	7	50.7	26	0.0339	0.0013	1.8103
Fuma	m805	PZA0154	7	72.2	26	0.043	0.0017	2.2966
Fuma	m830	PZA0102	7	117.6	26	0.0397	0.0015	2.1161
Fuma	m881	PZA0201	8	58	26	0.0446	0.0017	2.3793
Fuma	m923	PZA0070	8	88.5	26	0.0466	0.0018	2.4856
Fuma	m1081	PZA0100	10	49.2	26	0.0369	0.0014	1.9674
Fuma	m1106	PZA0252	10	101.9	26	0.0384	0.0015	2.0489
Gluc	m209	PZA0059	2	53.3	26	3.1988	0.123	2.6071
Gluc	m221	PZA0199	2	64.2	26	2.8707	0.1104	2.3397
Gluc	m315	PZA0050	3	38.3	26	3.2912	0.1266	2.6824
Gluc	m337	PZA0258	3	57.6	26	3.172	0.122	2.5853
Gluc	m429	PZA0218	3	146.8	26	2.911	0.112	2.3725
Gluc	m482	PZA0345	4	58.9	26	3.1006	0.1193	2.5271
Gluc	m548	PZA0019	5	3.5	26	3.6982	0.1422	3.0141
Gluc	m571	PZA0152	5	47	26	4.3372	0.1668	3.5349
Gluc	m625	PZA0014	5	76.9	26	4.1872	0.161	3.4127
Gluc	m774	PZA0368	7	48.4	26	4.1015	0.1577	3.3428
Gluc	m838	PZA0227	7	135	26	3.7348	0.1436	3.044
Gluc	m972	PZA0303	9	44.6	26	3.148	0.1211	2.5657
Gluc	m1046	PZA0007	10	33.9	26	4.2259	0.1625	3.4442
Glut	m87	PZA0353	1	99.3	26	0.0969	0.0037	2.6546
Glut	m262	PZA0352	2	97.5	26	0.0939	0.0036	2.5742
Glut	m409	PZA0261	3	120.7	26	0.1329	0.0051	3.6428
Glut	m577	PHM565	5	53.9	26	0.0839	0.0032	2.2985
Glut	m843	PZA0036	8	17.1	26	0.0948	0.0036	2.5981
Glut	m883	PZA0357	8	59.7	26	0.1008	0.0039	2.7634
Glut	m1101	PZA0107	10	83.2	26	0.1266	0.0049	3.4682
Mala	m41	PZA0024	1	59	26	0.2054	0.0079	2.9528
Mala	m191	PZA0220	2	17.8	26	0.2441	0.0094	3.5088
Mala	m230	PZA0063	2	73.5	26	0.1865	0.0072	2.6806
Mala	m322	PZA0147	3	54.8	26	0.2396	0.0092	3.4445
Mala	m411	PZA0314	3	127.7	26	0.1765	0.0068	2.5374
Mala	m426	PZA0168	3	145.3	26	0.1635	0.0063	2.3496
Mala	m624	PZA0179	5	75.6	26	0.1853	0.0071	2.6632
Mala	m834	PZA0127	7	121.1	26	0.286	0.011	4.1105
Mala	m1103	PZA0100	10	91	26	0.2549	0.0098	3.6631
Nitr	m5	PHM2244	1	9.7	26	0.0028	0.0001	2.3773

Nitr	m260	PZA0173:	2	91.5	26	0.0044	0.0002	3.7237
Nitr	m409	PZA0261:	3	120.7	24	0.0041	0.0002	3.7684
Nitr	m483	PZA0214:	4	60.6	25	0.0054	0.0002	4.7401
Nitr	m488	PZA0192:	4	69.8	26	0.0054	0.0002	4.5709
Nitr	m654	PZA0035:	5	100.2	26	0.0173	0.0007	14.5803
Nitr	m672	PZA0054:	5	123.1	26	0.0035	0.0001	2.9893
Prot	m406	PZA0273:	3	111.2	26	0.1626	0.0063	2.6939
Prot	m413	PZA0075:	3	129.8	26	0.1469	0.0057	2.4341
Prot	m616	PZA0304:	5	69.5	26	0.1985	0.0076	3.2896
Prot	m667	PZA0039:	5	110.9	26	0.1467	0.0056	2.4302
Prot	m898	PZA0011:	8	67.4	26	0.1647	0.0063	2.7285
Prot	m993	PZA0323:	9	56.7	26	0.2176	0.0084	3.6061
Prot	m1041	PZA0046:	10	31	26	0.1509	0.0058	2.501
Star	m3	PZA0212:	1	3.7	26	2.3431	0.0901	2.888
Star	m52	PZA0229:	1	65.7	26	3.1555	0.1214	3.8892
Star	m123	PZA0226:	1	149.7	26	2.2124	0.0851	2.7269
Star	m191	PZA0220:	2	17.8	26	2.3299	0.0896	2.8717
Star	m211	PZA0314:	2	54.9	26	4.4589	0.1715	5.4957
Star	m336	PZA0311:	3	57.3	26	3.8211	0.147	4.7096
Star	m540	PZA0190:	4	136.6	26	1.902	0.0732	2.3443
Star	m632	PZA0025:	5	81.7	26	3.6684	0.1411	4.5214
Star	m670	PZA0098:	5	114.3	26	2.6344	0.1013	3.247
Star	m770	PZA0334:	7	45.8	26	2.4628	0.0947	3.0354
Star	m914	PHM4757	8	80.2	26	2.579	0.0992	3.1787
Star	m933	PHM4786	8	100.3	26	3.1719	0.122	3.9094
Star	m946	PZA0028:	9	12.6	26	2.0702	0.0796	2.5516
Star	m1048	PZA0285:	10	35.8	26	3.5666	0.1372	4.396
Sucr	m28	PHM1361	1	39.2	26	6.9897	0.2688	2.8145
Sucr	m608	PHM5798	5	65.9	26	6.9401	0.2669	2.7945
Sucr	m715	PZA0105:	6	44.4	26	6.4752	0.249	2.6073
Sucr	m793	PZA0223:	7	51.2	26	6.9936	0.269	2.816
Sucr	m931	PZA0002:	8	98.2	26	7.0275	0.2703	2.8297
Prin1	m262	PZA0352:	2	97.5	26	222.312	8.5505	3.5573
Prin1	m409	PZA0261:	3	120.7	26	293.873	11.3028	4.7023
Prin1	m576	PZA0142:	5	53.6	26	181.103	6.9655	2.8979
Prin1	m674	PZA0316:	5	125.2	26	164.286	6.3187	2.6288
Prin1	m884	PZA0073:	8	59.7	26	193.524	7.4432	3.0966
Prin1	m924	PHM1562	8	88.5	26	154.219	5.9315	2.4677
Prin1	m995	PZA0232:	9	57.7	26	172.252	6.6251	2.7562
Prin1	m1106	PZA0252:	10	101.9	26	266.384	10.2455	4.2625
Prin2	m27	PZA0042:	1	37.8	26	101.264	3.8948	2.826
Prin2	m52	PZA0229:	1	65.7	26	130.11	5.0042	3.6311
Prin2	m112	PZA0066:	1	134.7	26	82.3139	3.1659	2.2972
Prin2	m185	PZA0090:	2	6.8	26	107.584	4.1379	3.0024
Prin2	m214	PZA0175:	2	56.9	26	133.38	5.13	3.7223

Prin2	m316	PHM4204	3	38.3	26	92.9001	3.5731	2.5926
Prin2	m339	PZA0050	3	57.7	26	109.353	4.2059	3.0518
Prin2	m632	PZA0025	5	81.7	26	105.651	4.0635	2.9485
Prin2	m670	PZA0098	5	114.3	26	117.647	4.5249	3.2832
Prin2	m715	PZA0105	6	44.4	26	101.353	3.8982	2.8285
Prin2	m770	PZA0334	7	45.8	26	191.174	7.3528	5.3352
Prin2	m883	PZA0357	8	59.7	26	94.5954	3.6383	2.6399
Prin2	m1010	PZA0225	9	74.2	26	85.8454	3.3017	2.3957
Prin2	m1044	PZA0296	10	33.3	26	128.399	4.9384	3.5833

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ProbF	Rsqr	Number of families		
		Negative Effect	Positive Effect	Total
8.55E-08	0.0115	7		7
1.98E-09	0.013	1	5	6
5.79E-24	0.0247		13	13
6.27E-06	0.0098	1	5	6
1.32E-05	0.0095	5	1	6
8.16E-08	0.0115	7	1	8
6.19E-12	0.0151		7	7
5.69E-05	0.0088	2	2	4
6.04E-10	0.0134	8		8
4.90E-11	0.0144	8		8
2.73E-05	0.0092		7	7
1.55E-09	0.0131		5	5
1.86E-12	0.0155		9	9
8.83E-07	0.0106	7		7
8.61E-19	0.0206	14		14
1.49E-07	0.0113	8		8
3.67E-05	0.009	1	5	6
2.68E-06	0.0101		6	6
3.56E-07	0.0108	8	1	9
8.69E-07	0.0105		7	7
3.01E-05	0.009		6	6
1.17E-18	0.0203	13		13
7.37E-09	0.0123	7		7
3.01E-09	0.0127	8		8
2.21E-07	0.011		7	7
4.17E-09	0.0135		2	2
7.46E-08	0.0123	2	1	3
6.36E-13	0.0145		2	2
2.10E-136	0.1116	1	2	3
1.03E-08	0.0129	1	4	5
3.48E-05	0.0096	1	7	8
1.05E-05	0.0102		6	6
8.51E-22	0.022	1	3	4
2.31E-15	0.0181	1	1	2
5.76E-08	0.0122	4	1	5
2.50E-06	0.0106	3	3	6
0.000153	0.0088	1	4	5
3.30E-05	0.0095	2	4	6
5.71E-13	0.0167	10		10
3.52E-05	0.0094	3		3
1.04E-05	0.01	3		3

7.41E-05	0.0104	3	1	4
0.003142	0.0083	2	3	5
0.006278	0.0079	3	1	4
0.000361	0.0095	4	1	5
7.97E-05	0.0104	3	4	7
0.002641	0.0084	2	1	3
3.80E-07	0.013	7	1	8
0.000258	0.0097	1	6	7
0.007151	0.0078	3	1	4
0.000198	0.0099	2	4	6
0.000801	0.0091		3	3
0.000102	0.0102	1	4	5
4.30E-05	0.0107	2	3	5
0.002393	0.0085	2	2	4
0.001322	0.0088	1	4	5
1.56E-05	0.0096	5		5
0.000141	0.0086	2	4	6
8.20E-06	0.0099	5		5
1.87E-05	0.0095	5	1	6
0.000108	0.0088	2	4	6
3.04E-05	0.0093	6		6
4.46E-07	0.0111	6	1	7
3.60E-09	0.013	4	1	5
1.14E-08	0.0126	4	3	7
2.19E-08	0.0123	9	1	10
3.40E-07	0.0112	4	6	10
2.20E-05	0.0095	2	3	5
8.48E-09	0.0127	3	5	8
1.04E-05	0.0107		6	6
2.05E-05	0.0104		5	5
1.27E-09	0.0147	7		7
0.000195	0.0093		5	5
1.67E-05	0.0105	1	5	6
4.06E-06	0.0112	1	6	7
6.70E-09	0.014		9	9
7.68E-07	0.0101	1	6	7
4.58E-09	0.012	1	7	8
8.30E-06	0.0092	7	3	10
8.41E-09	0.0118		7	7
2.79E-05	0.0087	7	1	8
0.00013	0.008	3	1	4
9.64E-06	0.0091	1	7	8
1.34E-11	0.0141		8	8
1.05E-09	0.0125		8	8
0.000104	0.0076	1	2	3

5.88E-10	0.0119		6	6
1.60E-09	0.0111	2	1	3
6.88E-14	0.0146		2	2
1.32E-13	0.0146	2		2
2.45E-61	0.0466	1	2	3
5.55E-07	0.0096	3		3
7.40E-06	0.0091	8	1	9
6.54E-05	0.0082	6		6
3.57E-08	0.0111	7		7
6.75E-05	0.0082	4		4
5.49E-06	0.0092	4	4	8
1.81E-09	0.0122	10		10
3.77E-05	0.0085	2	4	6
1.37E-06	0.0082	5	1	6
1.19E-10	0.0111	1	3	4
5.60E-06	0.0078	5		5
1.59E-06	0.0082	6		6
9.53E-18	0.0156	9		9
3.27E-14	0.0134	5	2	7
0.000136	0.0067	5		5
2.21E-13	0.0129	3	7	10
5.34E-08	0.0092		7	7
3.68E-07	0.0086	6		6
1.00E-07	0.009	3	3	6
9.77E-11	0.0111		6	6
2.48E-05	0.0073	5		5
7.84E-13	0.0125	3	5	8
2.60E-06	0.0076	6		6
3.09E-06	0.0076	2	5	7
1.55E-05	0.007	6		6
2.56E-06	0.0076	5		5
2.27E-06	0.0076		4	4
2.89E-09	0.0163	9		9
3.45E-14	0.0215		8	8
1.25E-06	0.0133	7		7
1.29E-05	0.012		6	6
2.10E-07	0.0142	8	2	10
4.96E-05	0.0113	1	4	5
4.32E-06	0.0126	2	5	7
2.94E-12	0.0195	7		7
2.37E-06	0.0093		7	7
1.44E-09	0.012	7		7
0.000197	0.0076	2	4	6
4.95E-07	0.0099		6	6
6.00E-10	0.0123	1	9	10

1.76E-05	0.0086		6	6
3.18E-07	0.0101	4	2	6
8.02E-07	0.0097	3	2	5
3.82E-08	0.0108	4	1	5
2.32E-06	0.0093	1	3	4
5.11E-17	0.0176		15	15
1.18E-05	0.0087	3	1	4
8.96E-05	0.0079	4	1	5
2.28E-09	0.0118	3	2	5

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