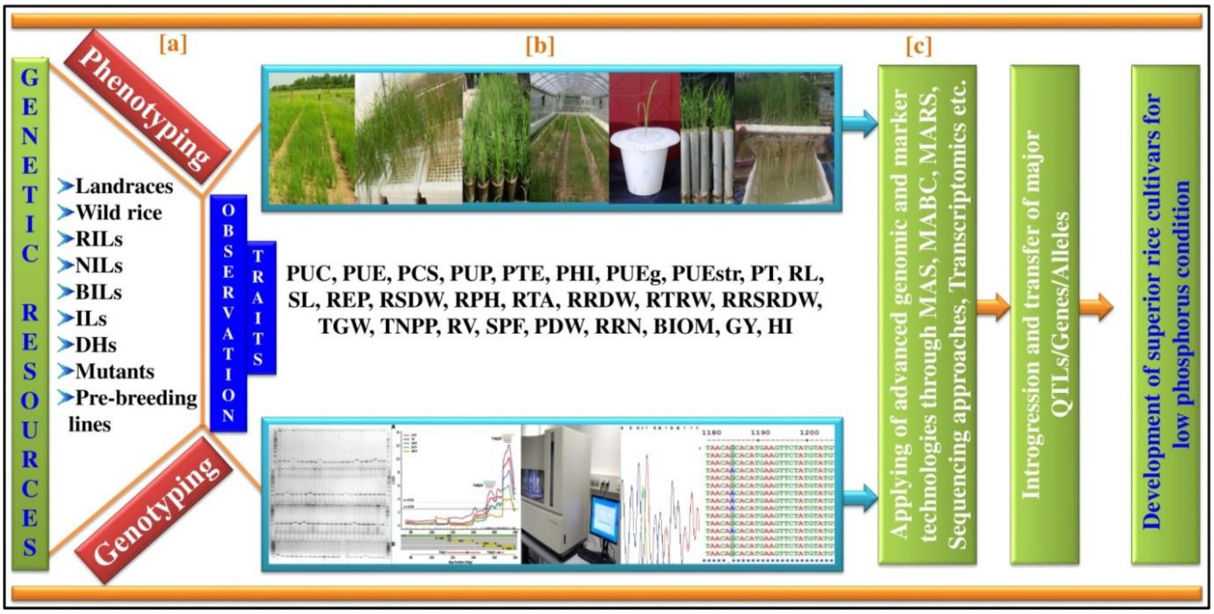

Figure S1. Combination of molecular breeding and advance genomics approaches for the increasing of rice grain yield under low phosphorus condition

The schematic representation of phenotypic and genotypic approaches to improve rice grain yield by applying molecular breeding and advanced genome sequencing techniques. (a) In the first instance, there is a need to be utilizing existing genetic resources, native landraces and mapping populations for the development of target traits of interest. (b) Characterization of morphological and physiological traits under low phosphorus condition with employing of various phenotypic screening methods. (c) Utilizing recent techniques of molecular markers for the development of genotypic information to identify and locate the QTLs and genes or alleles using linkage or/ association mapping and sequencing approaches. Genetic and QTLs information, further subsequently can be used in introgression and validation into elite breeding rice varieties to improve existing or / new lines suitable for low phosphorus condition.

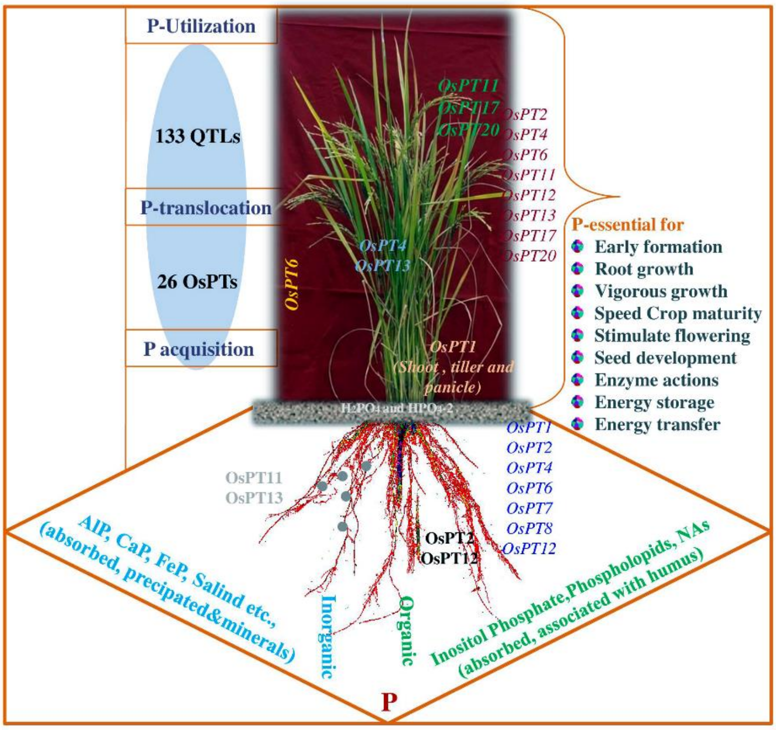

Figure S2. Depicted diagram of uptake and translocation of phosphorus from soil with associating of phosphate transporters

(***OsPT*-Direct Pi uptake from soil**, ***OsPT*-expressed in both vegetative and reproductive tissues**, *OsPT*-arbuscular mycorrhizal symbiosis, *OsPT*-dual role in Pi uptake and translocation, *OsPT*-stamen at 1d before flowering, ***OsPT*-flag leaf**, ***OsPT*-seed germination and root development**)

Table S1. List of QTLs associated with molecular markers under low phosphorus situation from diverse mapping populations in rice

S. No	QTLs associated traits	Interval markers	Mapping population	Type	Chr	LOD	PV	Reference
1	PUP	G227-C365	*Nipponbare × Kasalath*	BILs	2	2.82	5.8	Wissuwa et al. 1998
2		C498-R1954			6	3.52	9.8	
3		R1629-R2447			10	4.7	7.7	
4		G2140-C443			12	10.74	27.9	
5		G227-C365			2	2.82	5.8	
6		C498-R1954			6	3.52	9.8	
7		BIN1348-BIN1349	*Zhenshan 97 × Minghui 63*	RILs	10	-	5.5	Wang et al. 2014
8		BIN46-BIN47			1	-	4.7	
9		S14025-S13126	*Nipponbare × NIL-C443*	NILs	12	16.6	78.9	Wissuwa et al. 2002
10		S14025-S13126	*Nipponbare × NIL-C443*	F_3	12	11.5	28.1	
11	PUE	G227-C365	*Nipponbare × Kasalath*	BILs	2	5.22	9.8	Wissuwa et al. 1998
12		C946-R1854			4	4.65	9.4	
13		G2140-C443			12	6.57	19.1	
14		G227-C365			2	11.4	32.1	
15		CT221-C223	*ZYQ8 × JX17*	DHs	10	2.16	10.2	Feng et al. 2000
16	PUEg	BIN302-BIN303	*Zhenshan 97 × Minghui 63*	RILs	2	-	13.4	Wang et al. 2014
17		BIN1395-BIN1396			11	-	4.4	
18		BIN946-BIN947			6	-	4.1	
19	RRDW	RM410-RM553	*Yuefu × IRAT109*	ILs	9	-	5.15	Li et al. 2009
20		G200-C235	*ZYQ8 × JX17*	DHs	6	5.12	20.50	Feng et al. 2000
21		RM229-RM5349	*Yuefu × IRAT109*	ILs	11	>3.0	9.92	Li et al. 2009
22		RM145	*Shuhui 527 × Minghui 86*	ILs	2	-	9.60	Chao et al. 2015
23		RM521			2	-	62.2	
24		RM335			4	-	11.00	
25		RM142			4	-	11.50	
26		RM47			7	-	8.80	
27		RM160			9	-	9.90	
28		RM410–RM553	*Yuefu × IRAT109*	ILs	9	>3.0	5.15	Li et al. 2009
29		RG9-RG241	*IR20 × IR55178-3B-9-3*	RILs	12	12.05	47.0	Ni et al. 1998
30		E4/M8-3&E1/M7-7			6	5.80	32.3	
31	RTDW	RM259-RM576	*Yuefu × IRAT109*	ILs	1	-	-	Li et al. 2009
32		G200-C235	*ZYQ8 × JX17*	DHs	6	6.6	24.9	Feng et al. 2000

33		RM283	*Shuhui 527 × Minghui 86*	ILs	1	-	16.50	Chao et al. 2015
34		RM576			1	-	8.20	
35		RM16			3	-	10.60	
36		RM514			3	-	8.20	
37		RM335			4	-	11.00	
38		RM219			9	-	8.00	
39		RM219			9	-	8.00	
40		RM155			12	-	11.50	
41		RM511			12	-	13.00	
42	RSDW	G200-C235	*ZYQ8 × JX17*	DHs	6	6.79	25.2	Feng et al. 2000
43		RM283	*Shuhui 527 × Minghui 86*	ILs	1	-	16.50	Chao et al. 2015
44		RM9			1	-	6.80	
45		RM16			3	-	10.60	
46		RM574			5	-	14.70	
47		RM26			5	-	8.70	
48		RM589			6	-	10.30	
49		RM481			7	-	9.20	
50		RM47			7	-	8.80	
51		RM590			10		8.00	
52		RG9-RG241	*IR20 × IR55178-3B-9-3*	RILs	12	16.98	31.3	Ni et al. 1998
53		E3/M8-3-E1/M7-7			6	7.90	22.4	
54		RM322	*OM2395 x AS996*	BC_2F_3	2	>3.0	9.19	Nguyen and Bui 2006
55		RM247			12	>3.0	9.13	
56		RM155	*Shuhui 527 × Minghui 86*	ILs	12	-	11.50	Chao et al. 2015
57		RM511			12	-	13.00	
58		ATGTCC167A	*Gimbozu × Kasalath*	F_8	6	5.18	15.9	Shimizu et al. 2004
59		AGCTGG394A			1	4.30	12.3	
60		CACTAC1149B			10	3.79	11.3	
61	RRL	RM521	*Shuhui 527 × Minghui 86*	ILs	2	-	62.20	Chao et al. 2015
62		RM3295			5	-	16.60	
63		RM510			6	-	8.80	
64		RM3307			6	-	14.40	
65		RM481			7	-	9.20	
66		RM444			9	-	11.50	
67		RM511			12	-	13.00	
68		RM5926-RM224	*Yuefu × IRAT109*	ILs	11	-	8.68	Li et al. 2009
69		RM322	*OM2395 × AS996*	BC_2F_3	2	>3.0	9.19	Nguyen and Bui 2006

70		RM5926-RM224	*Yuefu × IRAT109*	ILs	11	>3.0	8.68	Li et al. 2009
71	RWRSR	RM3688	*Shuhui 527 × Minghui 86*	ILs	2	-	10.80	Chao et al. 2015
72		RM514		ILs	3	-	8.20	
73		RM538		ILs	5	-	8.00	
74		RM589		ILs	6	-	10.30	
75		RM510		ILs	6	-	8.80	
76		RM219		ILs	9	-	8.00	
77		RM184		ILs	10	-	13.40	
78		RM287		ILs	11	-	7.90	
79		RM155		ILs	12	-	11.50	
80	PNPP	RM283	*Shuhui 527 × Minghui 86*	ILs	1	-	16.50	Chao et al. 2015
81		RM169			5	-	8.50	
82		RM26			5	-	8.70	
83		RM536			11	-	13.00	
84	PUEstr	BIN302-BIN303	*Zhenshan 97 × Minghui 63*	RILs	2	-	6.3	Wang et al. 2014
85		BIN177-BIN178			1	-	4.9	
86	PT	BIN1130-BIN1131	*Zhenshan 97 × Minghui 63*	RILs	8	-	5.0	Wang et al. 2014
87		BIN709-BIN710			5	-	4.9	
88	PTE	BIN310-BIN311	*Zhenshan 97 × Minghui 63*	RILs	2	-	9.9	Wang et al. 2014
89		BIN1131-BIN1132			8	-	7.2	
90		BIN33-BIN34			1	-	6.4	
91	SPF	RM9	*Shuhui 527 × Minghui 86*	ILs	1	-	6.80	Chao et al. 2015
92		RM335			4	-	11.00	
93		RM164			5	-	10.00	
94		RM26			5	-	8.70	
95		RM5463			6	-	9.80	
96		RM254			11	-	9.70	
97	TGW	RM335	*Shuhui 527 × Minghui 86*	ILs	4	-	11.00	Chao et al. 2015
98		RM164			5	-	10.00	
99		RM5463			6	-	9.80	
100		RM481			7	-	9.20	
101		RM219			9	-	8.00	
102	RSL	RM247	*OM2395 × AS996*	BC_2F_3	12	>3.0	11.21	Nguyen and Bui 2006
103		RM316			9	>3.0	11.56	
104		RM291			5	>3.0	11.67	
105		RM235			12	>3.0	11.01	
106	TNPP	R374-C335	*Nipponbare × Kasalath*	BILs	4	4.37	9.8	Wissuwa et al. 1998

107		C901-G1406			12	3.9	9.5	
108		G2140-C443			12	7.87	20.6	
109	REP	RM439	*Nipponbare × Kasalath*	CSSLs	6	95.2	54.5	Shimizu et al. 2008
110		RM5814			6	95.2	54.5	
111		RM7555-RM3343			6	3.9	3.6	
112		RM30	*Gimbozu × Kasalath*	F_8	6	4.50	19.9	Shimizu et al. 2004
113	PDW	C1488-C63	*Nipponbare × Kasalath*	BILs	3	3.08	6.4	Wissuwa et al. 1998
114		C191-C498			6	4.71	9.7	
115		G2140-C443			12	10.5	26.5	
116	RTA	RG9-RG241	*IR20 × IR55178-3B-9-3*	RILs	12	16.51	42.9	Ni et al. 1998
117		E3/M8-3-E1/M7-7			6	7.82	27.8	
118	RRN	RM1112-RM1272	*Yuefu × IRAT109*	ILs	4	>3.0	-	Li et al. 2009
119		RM2334-RM3166			3	>3.0	9.61	
120	BIOM	BIN1342-BIN1343	*Zhenshan 97 × Minghui 63*	RILs	10	-	12.3	Wang et al. 2014
121		BIN31-BIN32			1	-	8.6	
122		BIN1008-BIN1009			7	-	7.8	
123	HI	BIN59-BIN60	*Zhenshan 97 × Minghui 63*	RILs	1	-	9.7	Wang et al. 2014
124		BIN1398-BIN1399			11	-	7.4	
125	PHI	BIN59-BIN60	*Zhenshan 97 × Minghui 63*	RILs	1	-	15.8	Wang et al. 2014
126		BIN310-BIN311			2	-	20.0	
127		BIN1392-BIN1393			11	-	4.4	
128	RPH	RM7269-RM5314	*Yuefu × IRAT109*	ILs	6	-	-	Li et al. 2009
129	RER	GGCACC(247A, 293B)H	*Gimbozu × Kasalath*	F_8	6	4.55	20.3	Shimizu et al. 2004
130	RPH	RM6911-RM492	*Yuefu × IRAT109*	ILs	2	>3.0	11.0	Li et al. 2009
131	RPUC	G200-C235	*ZYQ8 × JX17*	DHs	6	2.8	11.9	Feng et al. 2000
132	PCS	GCTACA474A	*Gimbozu × Kasalath*	F_8	6	6.46	24.6	Shimizu et al. 2004
133	RRV	RM6911-RM492	*Yuefu × IRAT109*	ILs	2	-	-	Li et al. 2009
132	RRN	RM2334-RM3166	*Yuefu × IRAT109*	ILs	3	-	9.49	Li et al. 2009
133	GY	RM200	*Shuhui 527 × Minghui 86*	ILs	1	-	16.20	Chao et al. 2015

PUP- Total P uptake; **PUE**- P use efficiency; **PUEg**- Grain P use efficiency; **RRDW**- Relative root dry weight; **RTDW** -Relative total dry weight; RSDW- Relative shoot dry weight; **RRL**- Relative root length; **RWRSR**- Relative weight of root and shoot ratio; **PNPP**- Panicle Number per Plant; **PUEstr**-Straw P use efficiency based on P accumulation in straw; **PT**- P translocation; **PTE**- P translocation efficiency; **SPF**- Spikelet Fertility; **TGW**-1000-Grain Weight; **RSL**- Relative Shoot Length; **TNPP**-Total Number of Panicle per Plant; **REP**- Root Elongation under Phosphorus deficiency; **PDW**- Plant dry weight; **RTA**- Relative tillering ability; **RRN**- Relative total root number; **BIOM**- Biomass; HI-Harvest index; **PHI**- P harvest index; **RPH**- Relative Plant Height; **RER**-Relative elongation ratio; **RPUC**-Relative P uptaken content; **PCS**- Phosphorus content in shoots; **RRV**-Relative root volume; **RRN**-Relative root number; **GY**-Grain yield.