

Supplementary Table 1. Descriptive statistics of quality-related traits in the population of 91 RILs derived from a cross between 'Chamdongjin' and 'Younghojinmi' across two years.

Year	Trait ^z	Mean	SD ^y	CV (%)	Median	Minimum	Maximum	Range	Skew	Kurtosis	SE	Unimodality ^x	Bimodality
2022	PC (%)	5.68	0.36	6.34	5.72	4.67	6.60	1.93	-0.17	-0.02	0.04	TRUE	FALSE
	AC (%)	19.06	0.35	1.84	19.07	18.13	20.08	1.95	0.03	0.67	0.04	TRUE	FALSE
	WT	48.35	1.85	3.83	48.65	44.40	52.85	8.45	-0.14	-0.36	0.19	TRUE	FALSE
	HR (%)	88.80	3.07	3.46	88.30	82.05	96.90	14.85	0.40	-0.32	0.32	TRUE	FALSE
	OR (%)	0.89	0.77	86.52	0.63	0.03	4.15	4.12	1.96	4.76	0.08	TRUE	FALSE
	DR (%)	0.75	0.25	33.33	0.72	0.23	1.68	1.45	0.73	1.14	0.03	TRUE	FALSE
	BR (%)	7.22	2.55	35.32	7.57	1.52	12.45	10.92	-0.30	-0.84	0.27	FALSE	TRUE
	CR (%)	0.37	0.22	59.46	0.40	0.03	0.98	0.95	0.15	-0.71	0.02	FALSE	TRUE
	CrR (%)	1.98	0.83	41.92	1.83	0.50	4.26	3.76	0.64	-0.15	0.09	FALSE	TRUE
	PaT (°C)	71.42	0.49	0.69	71.41	70.04	72.89	2.85	0.35	0.65	0.05	TRUE	FALSE
	PV (RVU)	230.41	6.76	2.93	231.43	213.32	252.22	38.90	0.08	0.43	0.71	TRUE	FALSE
	TV (RVU)	138.84	9.35	6.73	139.15	121.61	173.06	51.44	0.55	0.86	0.98	TRUE	FALSE
	FV (RVU)	231.35	9.66	4.18	231.61	215.25	264.28	49.03	0.67	0.59	1.01	FALSE	TRUE
	BD (RVU)	91.57	8.68	9.48	91.07	62.71	107.50	44.79	-0.45	0.39	0.91	TRUE	FALSE
	SB (RVU)	0.95	9.66	1016.84	0.39	-17.24	28.51	45.75	0.48	0.04	1.01	TRUE	FALSE
	Toyo	86.51	2.05	2.37	86.51	81.85	90.60	8.75	-0.20	-0.51	0.22	TRUE	FALSE
	HN	46.85	4.25	9.07	46.78	36.18	57.95	21.76	0.05	-0.35	0.45	TRUE	FALSE
	TN	36.63	2.40	6.55	36.39	30.83	49.21	18.38	1.71	7.10	0.25	TRUE	FALSE
	AN	56.77	4.57	8.05	57.85	42.70	65.02	22.32	-0.64	0.00	0.48	TRUE	FALSE
	SN	71.26	10.28	14.43	71.38	49.20	97.34	48.14	0.12	-0.45	1.08	TRUE	FALSE
2023	PC (%)	5.53	0.36	6.51	5.48	4.80	6.43	1.63	0.30	-0.49	0.04	TRUE	FALSE
	AC (%)	18.83	0.43	2.28	18.78	17.45	20.30	2.85	0.40	1.54	0.04	TRUE	FALSE
	WT	45.88	1.6	3.49	45.83	42.03	49.25	7.22	-0.01	-0.82	0.17	TRUE	FALSE
	HR (%)	88.80	2.22	2.50	88.58	83.65	94.62	10.97	0.24	-0.30	0.23	TRUE	FALSE
	OR (%)	0.92	0.75	81.52	0.75	0.03	3.60	3.57	1.54	2.50	0.08	TRUE	FALSE
	DR (%)	0.75	0.20	26.67	0.73	0.35	1.30	0.95	0.26	-0.27	0.02	TRUE	FALSE
	BR (%)	6.71	1.59	23.70	6.67	2.38	9.92	7.53	-0.39	-0.31	0.17	TRUE	FALSE
	CR (%)	1.14	0.62	54.39	1.00	0.18	2.93	2.75	0.83	0.20	0.06	TRUE	FALSE
	CrR (%)	1.68	0.73	43.45	1.55	0.60	4.18	3.58	0.99	0.94	0.08	TRUE	FALSE
	PaT (°C)	72.74	0.56	0.77	72.78	71.03	73.94	2.91	0.04	-0.02	0.06	TRUE	FALSE
	PV (RVU)	224.81	7.65	3.40	224.25	209.33	243.85	34.52	0.14	-0.58	0.80	TRUE	FALSE
	TV (RVU)	129.69	9.65	7.44	129.04	106.71	157.40	50.69	0.26	-0.02	1.01	TRUE	FALSE
	FV (RVU)	210.51	10.46	4.97	209.98	181.00	240.62	59.62	-0.02	0.43	1.10	TRUE	FALSE
	BD (RVU)	95.11	10.16	10.68	94.23	64.90	119.19	54.29	-0.07	-0.28	1.06	FALSE	TRUE
	SB (RVU)	-14.30	10.94	-76.50	-13.54	-40.56	18.33	58.90	0.08	-0.13	1.15	FALSE	TRUE
	Toyo	86.56	2.57	2.97	86.75	79.78	92.52	12.73	-0.24	0.16	0.27	TRUE	FALSE
	HN	57.70	5.43	9.41	57.48	43.41	74.39	30.97	0.15	0.41	0.57	TRUE	FALSE
	TN	37.59	2.29	6.09	37.62	32.55	43.80	11.25	0.15	-0.25	0.24	TRUE	FALSE
	AN	53.92	3.15	5.84	54.11	44.42	60.38	15.96	-0.47	0.40	0.33	TRUE	FALSE
	SN	70.71	7.10	10.04	69.95	57.10	93.15	36.06	0.56	0.33	0.74	TRUE	FALSE

^zPC: protein content, AC: amylose content, WT: whiteness, HR: head rice, OR: opaque rice, DR: damaged rice, BR: broken rice, CR: colored rice, CrR: cracked rice, Pat: pasting temperature, PV: peak viscosity, TV: trough viscosity, FV: final viscosity, BD: breakdown, SB: setback, Toyo: glossiness, HN: hardness, TN: toughness, AN: adhesiveness, SN: stickiness.

^ySD: standard deviation, CV: coefficient of variation, SE: standard error.

^xUnimodality and bimodality were determined using the LaplacesDemon package in R.

Supplementary Table 2. QTLs associated with quality-related traits identified in the recombinant inbred line population derived from a cross between 'Chamdongin' (P1) and 'Younghojinmi' (P2) during the years 2022-2023.

Trait ^z	QTL name	Chr. ^y	Position (cM)	Interval-flanking markers		LOD ^x	PVE ^w (%)	Add ^v	Putative gene ^u
				left	right				
PC	<i>PC3-1_2022</i>	3	97	chr03_14288844	chr03_16733441	4.3	18.5	-0.15	<i>GS3</i>
	<i>PC3-2_2022</i>	3	154	chr03_28852757	chr03_32608218	3.8	13.8	0.13	<i>OsPK8, OsTB1</i>
	<i>PC1-1_2023</i>	1	12	chr01_3257654	chr01_4209102	7.0	7.2	-0.15	<i>OsPLDα1</i>
	<i>PC1-2_2023</i>	1	346	KJ01_109	chr01_36649551	10.4	12.0	-0.21	<i>OsAAP6, SD1</i>
	<i>PC1-3_2023</i>	1	389	chr01_42234111	chr01_42482913	17.1	23.9	-0.28	
AC	<i>AC3_2022</i>	3	111	chr03_22407127	chr03_23491435	5.4	20.5	0.17	<i>OsPK8</i>
WT	<i>WT3_2022</i>	3	101	chr03_14288844	chr03_16733441	6.8	27.0	1.04	<i>GS3</i>
	<i>WT3_2023</i>	3	102	chr03_14288844	chr03_16733441	9.9	23.3	0.84	<i>GS3</i>
	<i>WT7-1_2023</i>	7	22	chr07_3108600	chr07_3190324	3.6	7.2	0.44	
	<i>WT7-2_2023</i>	7	119	chr07_26963593	chr07_27244224	6.1	13.0	-0.59	<i>GW7</i>
	<i>WT8_2023</i>	8	71	KJ08_086	chr08_20637053	6.5	13.9	0.61	
	<i>WT9_2023</i>	9	87	chr09_17680896	chr09_17872367	3.4	6.8	-0.43	
HR	<i>HR3_2022</i>	3	102	chr03_14288844	chr03_16733441	21.0	59.7	-2.59	<i>GS3</i>
	<i>HR7_2022</i>	7	22	chr07_3108600	chr07_3190324	4.4	7.9	-0.88	
	<i>HR3-1_2023</i>	3	15	chr03_2745334	chr03_4007709	5.7	14.1	0.89	
	<i>HR3-2_2023</i>	3	102	chr03_14288844	chr03_16733441	11.9	34.3	-1.44	<i>GS3</i>
BR	<i>BR3_2022</i>	3	102	chr03_14288844	chr03_16733441	26.1	64.9	2.29	<i>GS3</i>
	<i>BR7_2022</i>	7	22	chr07_3108600	chr07_3190324	4.1	5.4	0.62	
	<i>BR3_2023</i>	3	102	chr03_14288844	chr03_16733441	9.9	38.4	0.99	<i>GS3</i>
CR	<i>CR3_2022</i>	3	102	chr03_14288844	chr03_16733441	25.0	67.7	0.20	<i>GS3</i>
	<i>CR3_2023</i>	3	102	chr03_14288844	chr03_16733441	4.4	20.5	0.29	<i>GS3</i>
CrR	<i>CrR3_2022</i>	3	102	chr03_14288844	chr03_16733441	4.3	10.7	-0.33	<i>GS3</i>
PaT	<i>PaT3_2022</i>	3	99	chr03_14288844	chr03_16733441	5.5	23.2	-0.25	<i>GS3</i>
	<i>PaT8_2022</i>	8	1	chr08_1044621	chr08_1282290	4.5	15.3	-0.20	
	<i>PaT3_2023</i>	3	99	chr03_14288844	chr03_16733441	3.3	17.3	-0.24	<i>GS3</i>
PV	<i>PV1_2022</i>	1	12	chr01_3257654	chr01_4209102	5.0	17.6	-2.84	<i>OsPLDα1</i>
	<i>PV1_2023</i>	1	25	chr01_4209102	chr01_5104605	3.9	19.5	-3.08	<i>OsPLDα1</i>
TV	<i>TV2_2022</i>	2	138	chr02_28487730	chr02_29187837	4.2	15.3	3.83	
	<i>TV3_2022</i>	3	160	chr03_28852757	chr03_32608218	3.7	17.7	4.10	<i>OsPK8, OsTB1</i>
	<i>TV3-1_2023</i>	3	0	chr03_204361	chr03_517088	5.2	19.0	-4.24	<i>qLTG3-1</i>
	<i>TV3-2_2023</i>	3	152	chr03_24699522	chr03_28852757	3.0	11.8	3.29	<i>OsPK8, OsTB1</i>
FV	<i>FV2_2022</i>	2	149	chr02_32118114	chr02_33208146	3.9	14.2	3.85	
	<i>FV3_2022</i>	3	145	chr03_24699522	chr03_28852757	3.3	16.9	4.17	<i>OsPK8, OsTB1</i>
	<i>FV3_2023</i>	3	149	chr03_24699522	chr03_28852757	3.4	14.1	4.59	<i>OsPK8, OsTB1</i>
BD	<i>BD3-1_2022</i>	3	0	chr03_204361	chr03_517088	8.3	24.1	4.65	<i>qLTG3-1</i>
	<i>BD3-2_2022</i>	3	121	chr03_23491435	chr03_23957624	5.3	15.6	-3.67	
	<i>BD3-1_2023</i>	3	0	chr03_204361	chr03_517088	6.9	26.0	5.14	<i>qLTG3-1</i>
	<i>BD3-2_2023</i>	3	105	chr03_17092696	chr03_19143571	4.2	15.1	-3.93	<i>OsSAC3</i>
SB	<i>SB1_2022</i>	1	232	chr01_22048209	chr01_27055210	5.0	12.1	3.67	
	<i>SB3-1_2022</i>	3	0	chr03_204361	chr03_517088	7.0	15.5	-4.18	<i>qLTG3-1</i>
	<i>SB3-2_2022</i>	3	111	chr03_22407127	chr03_23491435	6.9	15.5	4.17	
	<i>SB6_2022</i>	6	138	chr06_26747288	chr06_27209983	4.2	9.7	3.22	
	<i>SB3-1_2023</i>	3	0	chr03_204361	chr03_517088	5.8	18.7	-4.99	<i>qLTG3-1</i>

Supplementary Table 2. Continued.

Trait ^z	QTL name	Chr. ^y	Position (cM)	Interval-flanking markers		LOD ^x	PVE ^w (%)	Add ^v	Putative gene ^u
				left	right				
Toyo	<i>SB3-2_2023</i>	3	105	chr03_17092696	chr03_19143571	4.0	12.3	4.08	<i>OsSAC3</i>
	<i>Toyo1_2023</i>	1	339	KJ01_109	chr01_36649551	5.3	18.6	1.81	<i>OsAAP6, SD1</i>
	<i>Toyo7_2023</i>	7	107	chr07_24575395	chr07_24674898	4.3	9.2	1.08	<i>GW7</i>
AN	<i>AN1_2022</i>	1	10	chr01_2103204	chr01_2363715	3.8	11.3	1.29	
	<i>AN2_2022</i>	2	168	chr02_34635870	chr02_35088373	4.8	14.7	-1.47	
	<i>AN3_2022</i>	3	102	chr03_14288844	chr03_16733441	6.8	21.8	1.89	<i>GS3</i>
	<i>AN8_2022</i>	8	12	chr08_2479524	KJ08_009	3.3	9.6	1.19	
SN	<i>AN2_2023</i>	2	168	chr02_34635870	chr02_35088373	3.2	12.7	-1.17	
	<i>SN1_2022</i>	1	10	chr01_2103204	chr01_2363715	4.5	13.8	3.22	
	<i>SN2_2022</i>	2	168	chr02_34635870	chr02_35088373	4.0	12.0	-3.02	
	<i>SN3_2022</i>	3	102	chr03_14288844	chr03_16733441	5.9	18.5	3.95	<i>GS3</i>
	<i>SN8_2022</i>	8	12	chr08_2479524	KJ08_009	4.1	12.3	3.06	<i>Hd18</i>
	<i>SN1_2023</i>	1	12	chr01_3257654	chr01_4209102	5.8	23.9	3.40	<i>OsPLDα1</i>

^zPC: protein content, AC: amylose content, WT: whiteness, HR: head rice, OR: opaque rice, BR: broken rice, CR: colored rice, CrR: cracked rice, PaT: pasting temperature, PV: peak viscosity, TV: trough viscosity, FV: final viscosity, BD: breakdown, SB: setback, Toyo: glossiness, AN: adhesiveness, SN: stickiness.

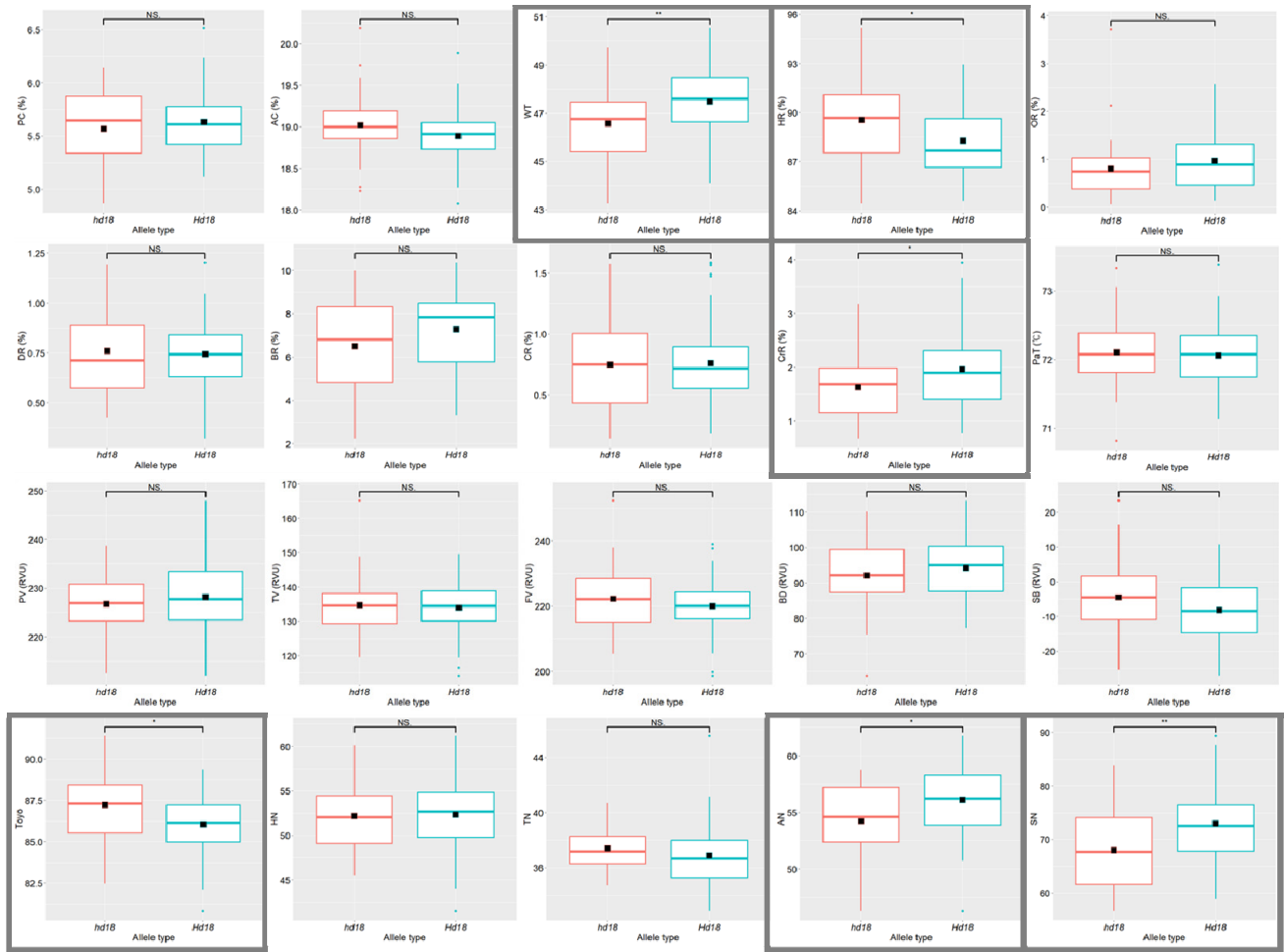
^yChromosome number, ^xLogarithm of the odds score, ^wPhenotypic variation explained by the QTL.

^vAdditive effect, add=(P1-P2)/2, the positive value of the additive effect indicates that the allele from Chamdongjin (P1) contributes to an increase in the trait value.

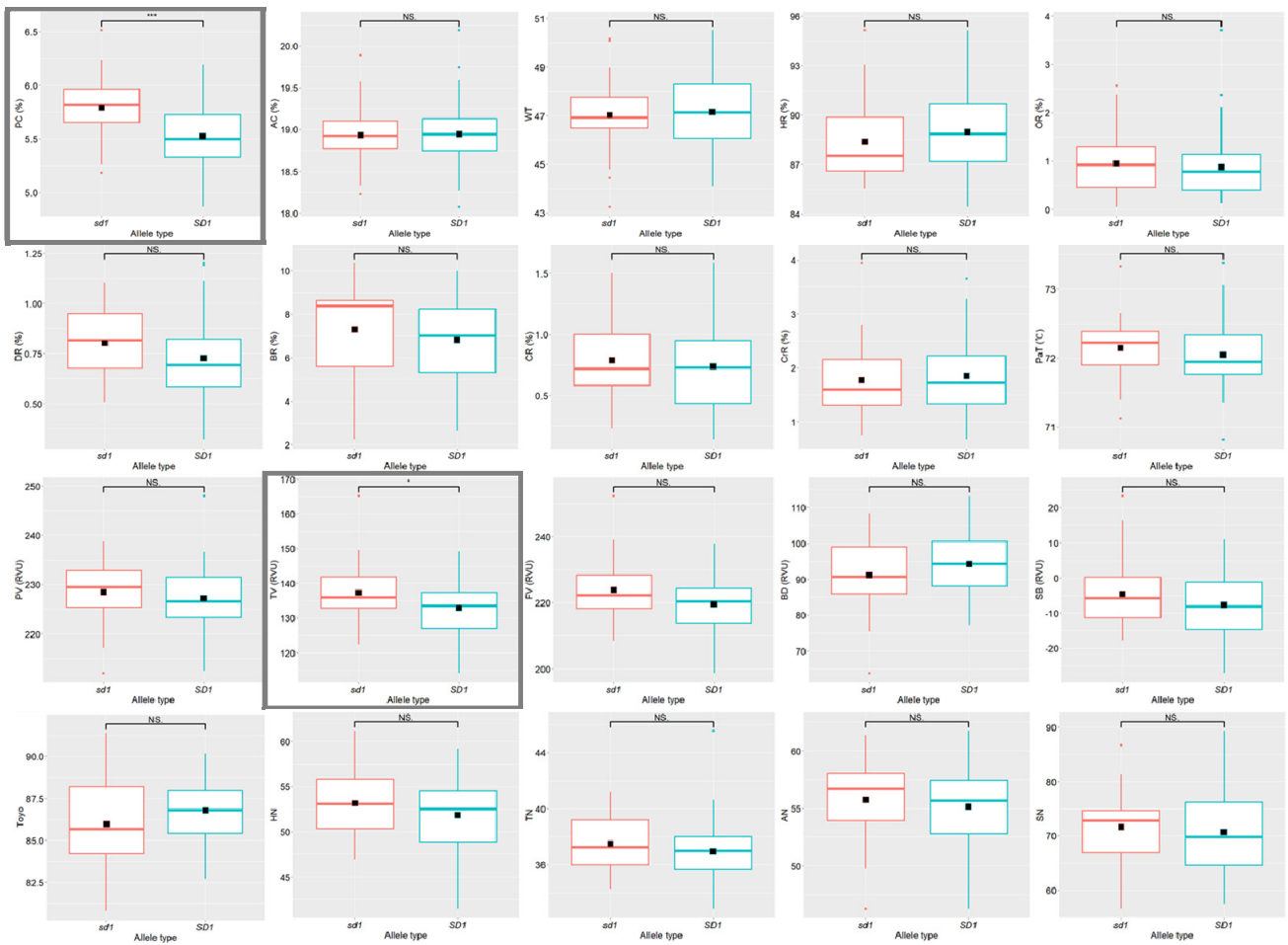
^u*GS3*: Os03g0407400 (chr03:16729501..16735109), *OsPK8*: Os03g0672300 (chr03:26526743..26530676), *OsTBI*: Os03g0706500 (chr03:28428504..28430438), *OsPLDα1*: Os01g0172400 (chr01:3724667..3728791), *OsAAP6 (qPC1)*: Os01g0878700 (chr01:38133475..38137770), *SD1*: Os01g0883800 (chr01:38382385..38385469), *GW7*: Os07g0603300 (chr07:24664328..24669321), *qLTG3-1*: Os03g0103300 (chr03:219979..220919), *OsSAC3*: Os03g0429800 (chr03:17985619..17998387), *Hd18*: Os08g0143400 (chr08:2385537..2389276).

Supplementary Table 3. Sequence analysis of nucleotide variations involved in the function of putative genes.

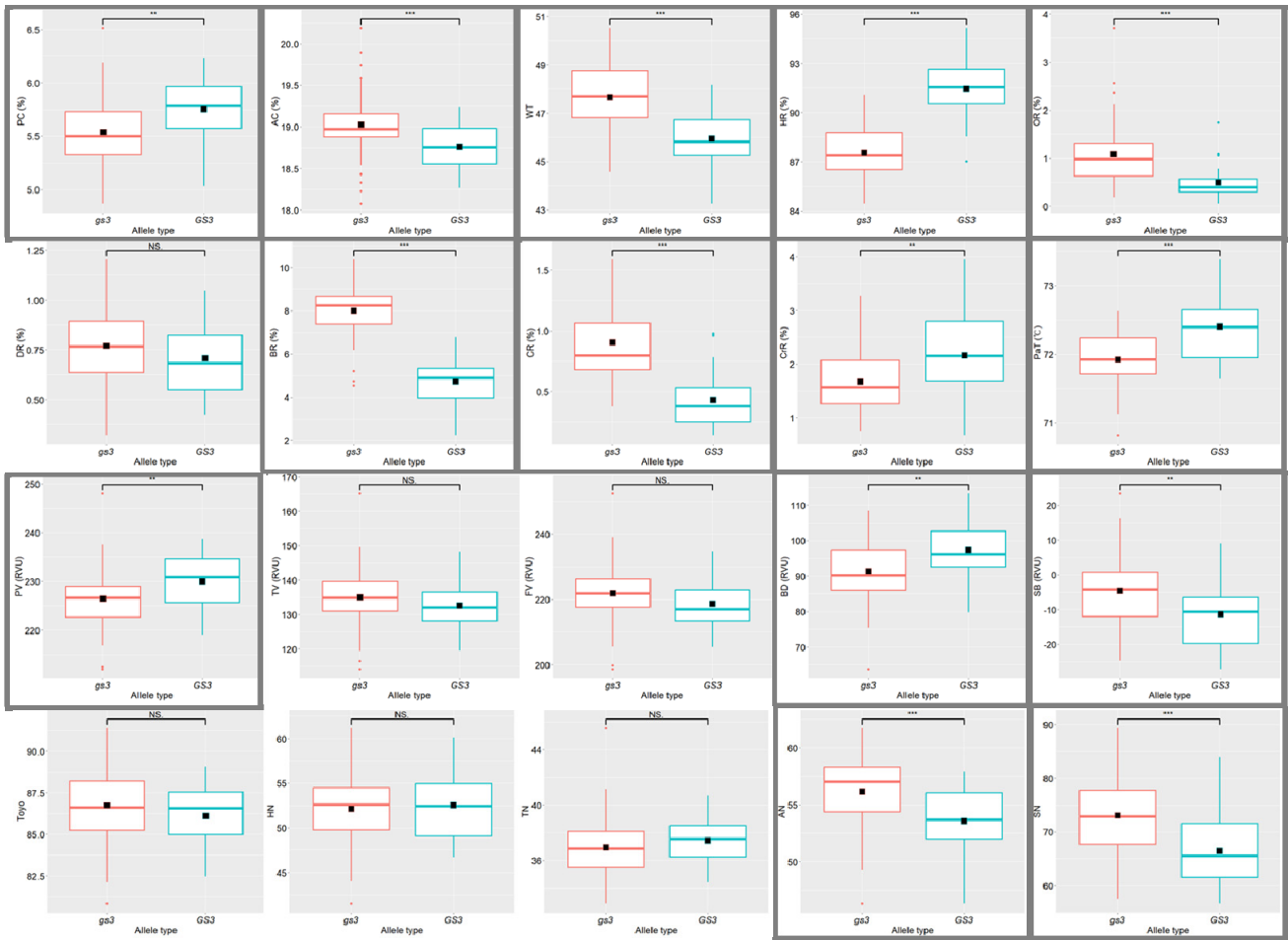
Var ID	Variants type	Chromosome	Position (bp)	Reference allele	Alternative allele	Chamdongjin genotype	Younghojimi genotype	snpEff annotation	Putative gene
vg0326532662	SNP	3	26,532,662	C	T	T/T	ref. allele	missense_variant ; p.Gly461Asp; MODERATE	<i>OsPK8</i>
vg0724666092	SNP	7	24,666,092	T	C	C/C	ref. allele	missense_variant ; p.Ser620Gly; MODERATE	<i>GW7</i>
vg0724666398	SNP	7	24,666,398	G	A	A/A	ref. allele	missense_variant ; p.Pro518Ser; MODERATE	<i>GW7</i>



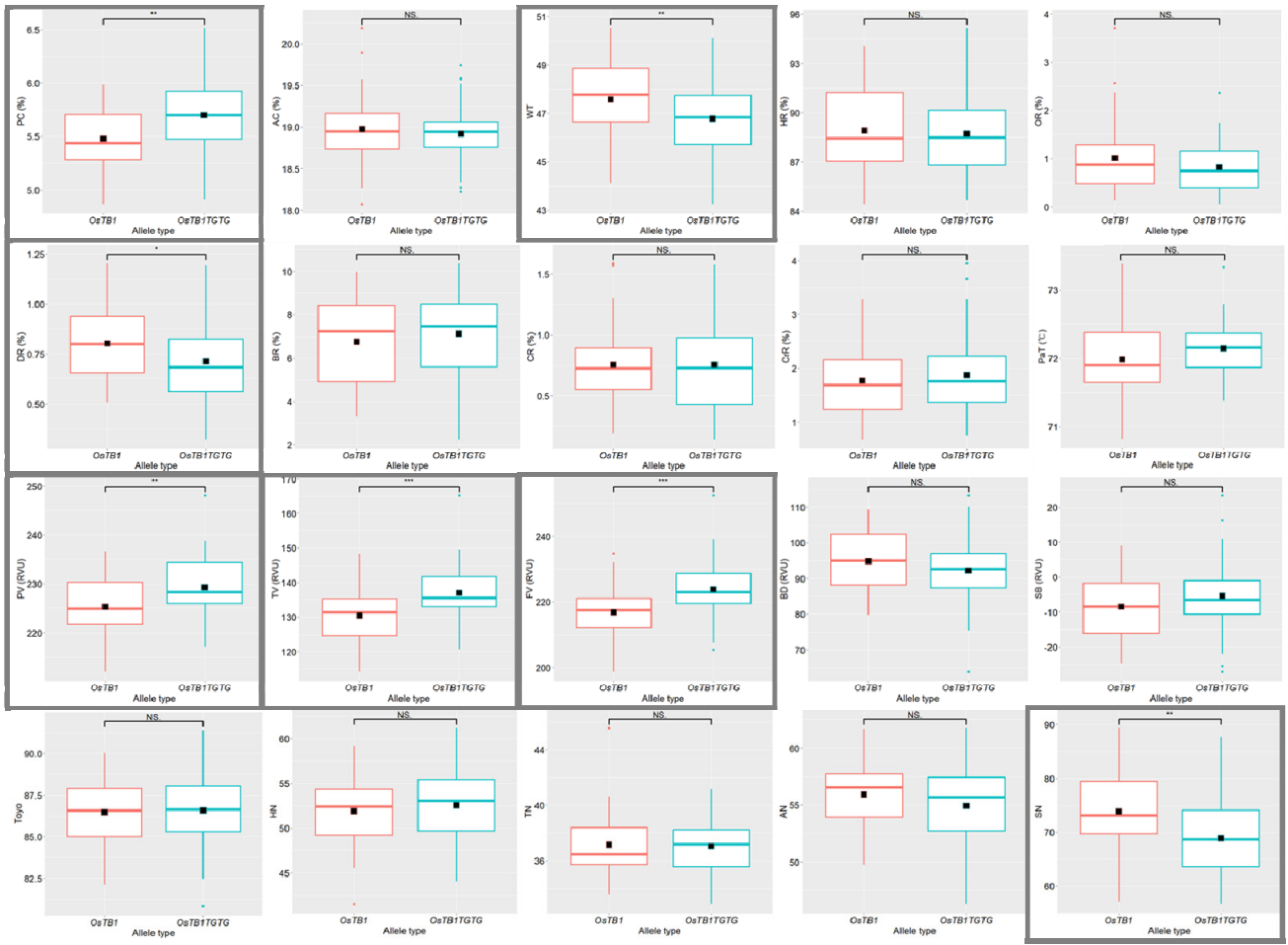
Supplementary Fig. 1. Effects of *Hd18* alleles on the phenotypes of quality-related traits in the CY_RIL population. Box plots showing the variation in protein content (PC), amylose content (AC), whiteness (WT), head rice (HR), opaque rice (OR), damaged rice (DR), broken rice (BR), colored rice CR, cracked rice (CrR), pasting temperature (Pat), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown (BD), setback (SB) glossiness (Toyo), hardness (HN), toughness (TN), adhesiveness (AN), and stickiness (SN) by allele types, *Hd18* (Chamdongjin type) and *hd18* (Younghojinmi type). The black rectangles indicate the means of each phenotype by allele types. NS, *, and ** indicate no significant, significance at the 0.05 and 0.01 probability levels by *t*-test, respectively. The outer gray borders of the figures indicate the traits that are statistically different.



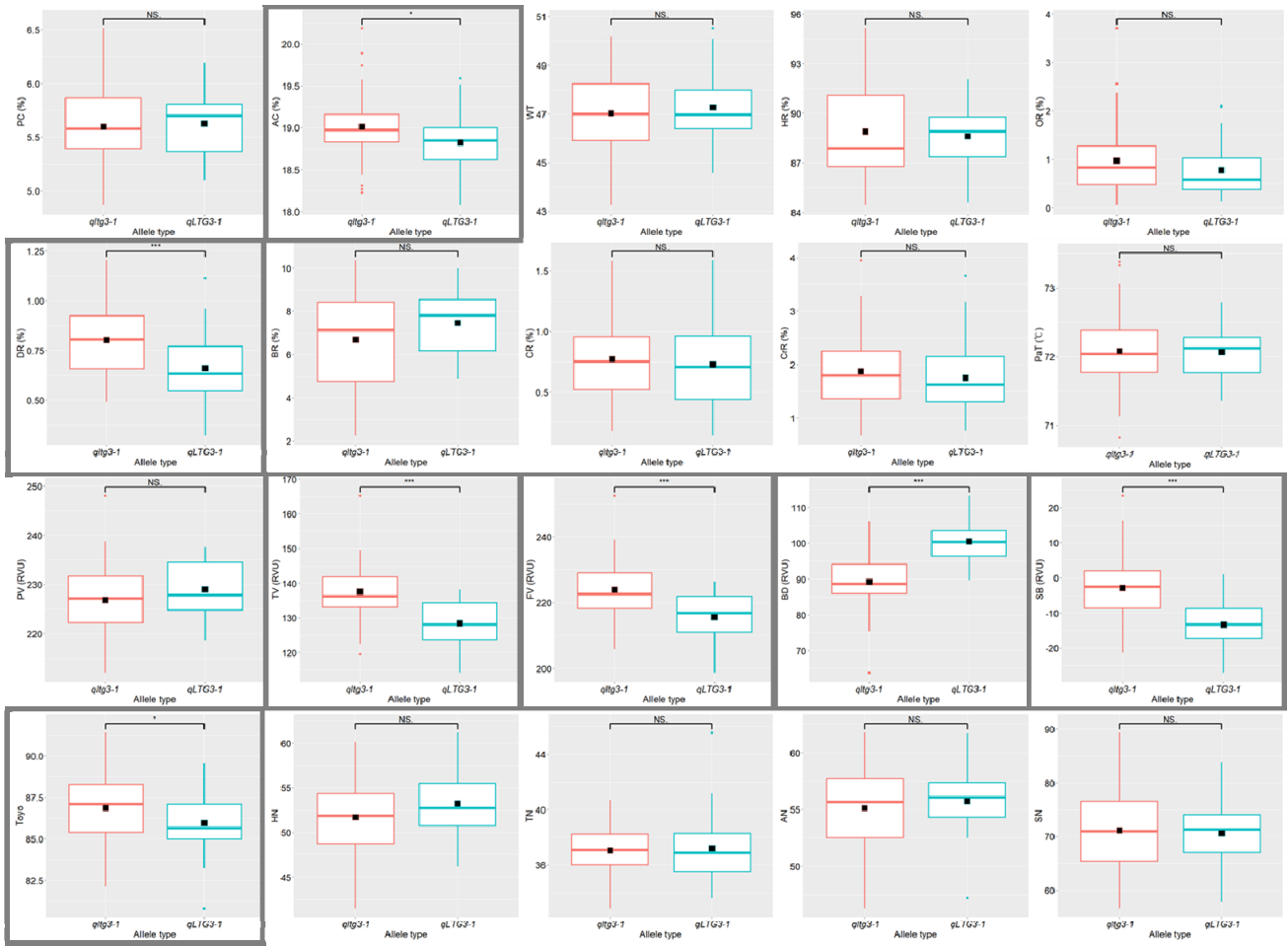
Supplementary Fig. 2. Effects of *SD1* alleles on the phenotypes of quality-related traits in the CY_RIL population. Box plots showing the variation in protein content (PC), amylose content (AC), whiteness (WT), head rice (HR), opaque rice (OR), damaged rice (DR), broken rice (BR), colored rice CR, cracked rice (CrR), pasting temperature (Pat), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown (BD), setback (SB), glossiness (Toyo), hardness (HN), toughness (TN), adhesiveness (AN), and stickiness (SN) by allele types, *SD1* (Chamdongjin type) and *sd1* (Younghojinmi type). The black rectangles indicate the means of each phenotype by allele types. NS, *, and *** indicate no significant, significance at the 0.05 and 0.001 probability levels by *t*-test, respectively. The outer gray borders of the figures indicate the traits that are statistically different.



Supplementary Fig. 3. Effects of *GS3* alleles on the phenotypes of quality-related traits in the CY_RIL population. Box plots showing the variation in protein content (PC), amylose content (AC), whiteness (WT), head rice (HR), opaque rice (OR), damaged rice (DR), broken rice (BR), colored rice (CR), cracked rice (CrR), pasting temperature (Pat), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown (BD), setback (SB) glossiness (Toyo), hardness (HN), toughness (TN), adhesiveness (AN), and stickiness (SN) by allele types, *gs3* (Chamdongjin type) and *GS3* (Younghojinmi type). The black rectangles indicate the means of each phenotype by allele types. NS, **, and *** indicate no significant, significance at the 0.01 and 0.001 probability levels by *t*-test, respectively. The outer gray borders of the figures indicate the traits that are statistically different.



Supplementary Fig. 4. Effects of *OsTB1* alleles on the phenotypes of quality-related traits in the CY_RIL population. Box plots showing the variation in protein content (PC), amylose content (AC), whiteness (WT), head rice (HR), opaque rice (OR), damaged rice (DR), broken rice (BR), colored rice (CR), cracked rice (CrR), pasting temperature (Pat), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown (BD), setback (SB), glossiness (Toyo), hardness (HN), toughness (TN), adhesiveness (AN), and stickiness (SN) by allele types, *OsTB1^{TGTG}* (Chamdongjin type) and *OsTB1* (Younghojinmi type). The black rectangles indicate the means of each phenotype by allele types. NS, *, **, and *** indicate no significant, significance at the 0.05, 0.01, and 0.001 probability levels by *t*-test, respectively. The outer gray borders of the figures indicate the traits that are statistically different.



Supplementary Fig. 5. Effects of *qLTG3-1* alleles on the phenotypes of quality-related traits in the CY_RIL population. Box plots showing the variation in protein content (PC), amylose content (AC), whiteness (WT), head rice (HR), opaque rice (OR), damaged rice (DR), broken rice (BR), colored rice (CR), cracked rice (CrR), pasting temperature (Pat), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), breakdown (BD), setback (SB), glossiness (Toyo), hardness (HN), toughness (TN), adhesiveness (AN), and stickiness (SN) by allele types, *qLTG3-1* (Chamdongjin type) and *qltg3-1* (Younghojinmi type). The black rectangles indicate the means of each phenotype by allele types. NS, *, **, and *** indicate no significant, significance at the 0.05, 0.01, and 0.001 probability levels by *t*-test, respectively. The outer gray borders of the figures indicate the traits that are statistically different.