

QTL analysis for chlorophyll content under low nitrogen conditions in RILs derived from Korean *japonica* rice to improve yield potential

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Abstract

The flag leaf of rice supplies carbon assimilates to the panicle during the ripening stage. The high chlorophyll content of flag leaf under low nitrogen conditions could increase photosynthesis and it is one of the source traits that affect yield in rice. RIL population consists of 88 lines derived from a cross between two Korean *japonica*, JJ625LG (large grain breeding line) and Namchan (high-yielding variety under low nitrogen conditions). Two parents and 88 RILs were planted by two replications at the paddy field treated with low nitrogen fertilizer (4.5kg/10a). The chlorophyll content of flag leaves was collected at the full flowering stage using SPAD-502 plus. The genotyping of RILs was conducted using Target Capture Sequencing, and 511 informative SNPs were obtained. JJ625LG showed higher Chlorophyll contents of flag leaf and earlier heading date than Namchan. The average and range for chlorophyll contents of RILs were 39.1 and 35.2~44.1, respectively. The linkage map of RILs was constructed using 521 SNPs and represented 1841.3 cM for the total genetic length. Four QTLs for chlorophyll content were detected on chromosomes 1 and 8, explaining 70.7% of phenotypic variation. All alleles derived from JJ625LG showed a positive effect and *qCCF1.1* presented the highest LOD, PVE, and additive effect among four QTLs. Besides, three heading date QTLs were identified on chromosomes 1, 2, and 8. *qDTH8* was collocated with the same marker interval of *qCCF8*, and *qDTH1* was mapped on 13 cM upstream of *qCCF1.2*. This result implies chlorophyll content could be related to the heading date in this population. QTLs identified in this study would be applied to improve yield potential under low nitrogen conditions.

Phenotypic variation

Table 1. Phenotypic variation in 88 RIL population derived from a cross between JJ625 and Namchan.

Trait	JJ625	Namchan	RILs (n=88)				
			Mean	Min	Max	SE	Skewness Kurtosis
Chlorophyll content in flag leaf	41.4	36.9	39.1	35.2	44.1	2.04	0.12 -0.81
Days to heading	80	82.5	81.7	74.0	89.5	3.44	0.26 -0.30

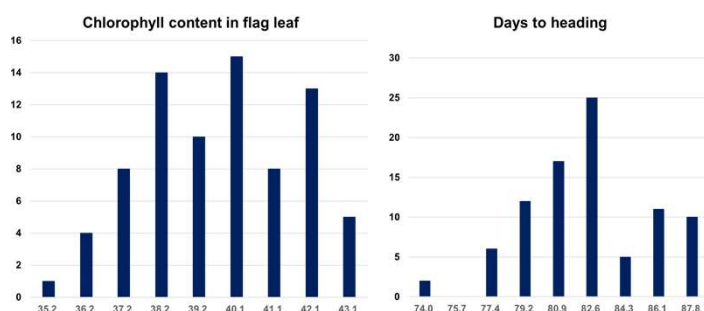


Figure 1. Histograms for chlorophyll content of flag leaf and days to heading in RIL population derived from JJ625 and Namchan

Linkage map construction and QTL analysis

Table 2. Information for linkage map of RIL population.

	Ch1	Ch2	Ch3	Ch4	Ch5	Ch6	Ch7	Ch8	Ch9	Ch10	Ch11	Ch12	Total
Number of SNPs	74	59	40	31	43	39	43	50	40	24	41	27	511
Size of linkage map (cM)	226.7	211.4	162.6	154.2	154.8	125.7	166.2	148.4	105.4	118.0	103.4	164.5	1841.3
Average interval (cM)	3.1	3.6	4.2	5.1	3.7	3.3	4.0	3.0	2.7	5.1	2.6	6.3	3.6

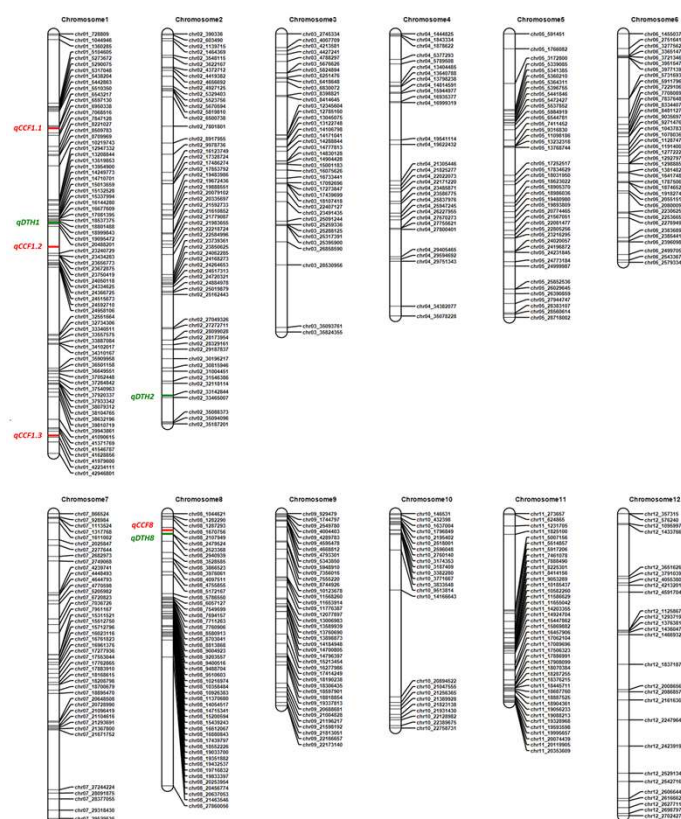


Figure 2. Linkage map of RIL population was constructed using 511 informative SNPs. QTLs for chlorophyll content in flag leaf (CCF) and days to heading (DTH) were presented on those position as red and green color, respectively.

Table 3. QTLs detected in the RIL population derived from a cross between JJ625 and Namchan.

Trait	QTL	Chr.	Position	Left marker	Right marker	LOD	PVE(%)	Add
Chlorophyll content of flag leaf	<i>qCCF1.1</i>	1	51	chr01_6597130	chr01_6950338	15.8	35.9	1.19
	<i>qCCF1.2</i>	1	115	chr01_20488201	chr01_23240729	5.8	12.6	0.70
	<i>qCCF1.3</i>	1	217	chr01_41628856	chr01_41979600	5.1	8.8	0.59
	<i>qCCF8</i>	8	9	chr08_2107949	chr08_2479524	7.5	13.4	0.72
Days to heading	<i>qDTH1</i>	1	102	chr01_18999843	chr01_19095472	5.0	13.7	-1.16
	<i>qDTH2</i>	2	196	chr02_33142844	chr02_33465007	3.7	9.3	0.95
	<i>qDTH8</i>	8	11	chr08_2107949	chr08_2479524	13.6	45.1	-2.09