Analysis of variations in white-belly and white-core rice kernel across the rice panicle and the effect of panicle type

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ABSTRACT

Twenty-four M4 mutants derived from japonica rice cultivar Wuyujing3 were used to investigate the variation in occurrence of white-belly rice kernel (WBRK) and white-core rice kernel (WCRK) among different positions within panicle.

These mutants were of four panicle types, namely the compact, intermediate, loose, and chicken toe panicle.

Results include:

• Grains located on primary and top rachis branches had higher WBRK and WCRK percentage than those on secondary and bottom rachis branches.

2. WCRK exhibited larger variation among different grain positions than that of WBRK.

3. There were significant differences in WCRK/ WBRK among grain positions within a panicle, with primary and top rachis branches having higher values than the secondary and bottom.

4. Panicle type showed no significant effect on the pattern of WBRK and WCRK occurrence within panicle.

The results indicate different mechanism between WBRK and WCRK formation with regard to grain position within panicle and are of value for breeding and agronomic practices aimed at lowering chalky grain rate.

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INTRODUCTION

☐Plant type became the focus of rice breeders at the end of last century, with stem, leaf, and tiller being the target traits. Panicle is the key organ for rice yield formation, and panicle type has received much attention recently.

☐According to grain density of panicle, japonica rice can be grouped into three types: compact panicle (CP), loose panicle (LP), and intermediate panicle (IP).

☐In recent two decades, many CP cultivars, characterized by short panicle and high grain density within a panicle, were intensively planted in China's main japonica rice production areas of Heilongjiang, Jilin, Liaoning, Jiangsu, and Zhejiang provinces.

☐In comparison with LP cultivars, CP cultivars have higher yield potential, possibly due to the improvement in micro-meteorological conditions of plants and consequently the higher utilization efficiency of solar energy.

☐We had identified a total of 236 japonica rice mutants with stable traits after four consecutive years (2007-2010). Among them, 24 mutants were selected, covering the CP, IP, and LP type, and a special panicle type, chicken toe type (CTP).

☐The objectives of this study were:

(1) to compare the panicle architecture among the three types;

(2) to investigate occurrence of WBRK and WCRK within panicle, and

(3) to elucidate the effect of panicle type on chalky grain rate and discuss its implication for mechanism of chalkiness formation.

METHODS AND MATERIALS

The M4 japonica rice mutants were used as test materials in the experiment, which derived from *japonica* rice cultivar Wuyujing3 by treating with 0.4% ethyl methane sulfonate. According to grain density of panicle and curvature of panicle neck, we selected 24 rice mutants with four types (Fig.1): compact panicle (CP), loose panicle (LP), intermediate panicle (IP), and chicken toe panicle (CTP). Six mutants with contrasting grain number/panicle of each panicle type were used.

Grains were collected separately from six positions on each panicle, i.e. top primary, top secondary, middle primary, middle secondary, bottom primary and bottom secondary rachis branches.

Ratio of perfect, white-belly rice kernel (WBRK), White-core rice kernel (WCRK), and other imperfect grains (white-back, green, opaque, milky and misshaped) was calculated.

RESULTS

1. Marked difference was found in WBRK and WCRK among different positions within a panicle for all types of panicle, with the order of primary rachis > secondary rachis, and top> middle> the bottom rachis.
2. The WCRK exhibited larger variation among different grain positions within a panicle than that of WBRK. For the four types, coefficient of variation of WBRK ranged from 21.34% for loose panicle to 43.45% for compact panicle. By contrast, CV of WCRK ranged from 68.31% for intermediate panicle to 102.35% for chicken toe panicle.
3. A dramatic drop of WCRK was detected from the top to bottom branches, with averaged values in primary rachis across the four types being 23.61% for top rachis and 6.92% for bottom rachis.

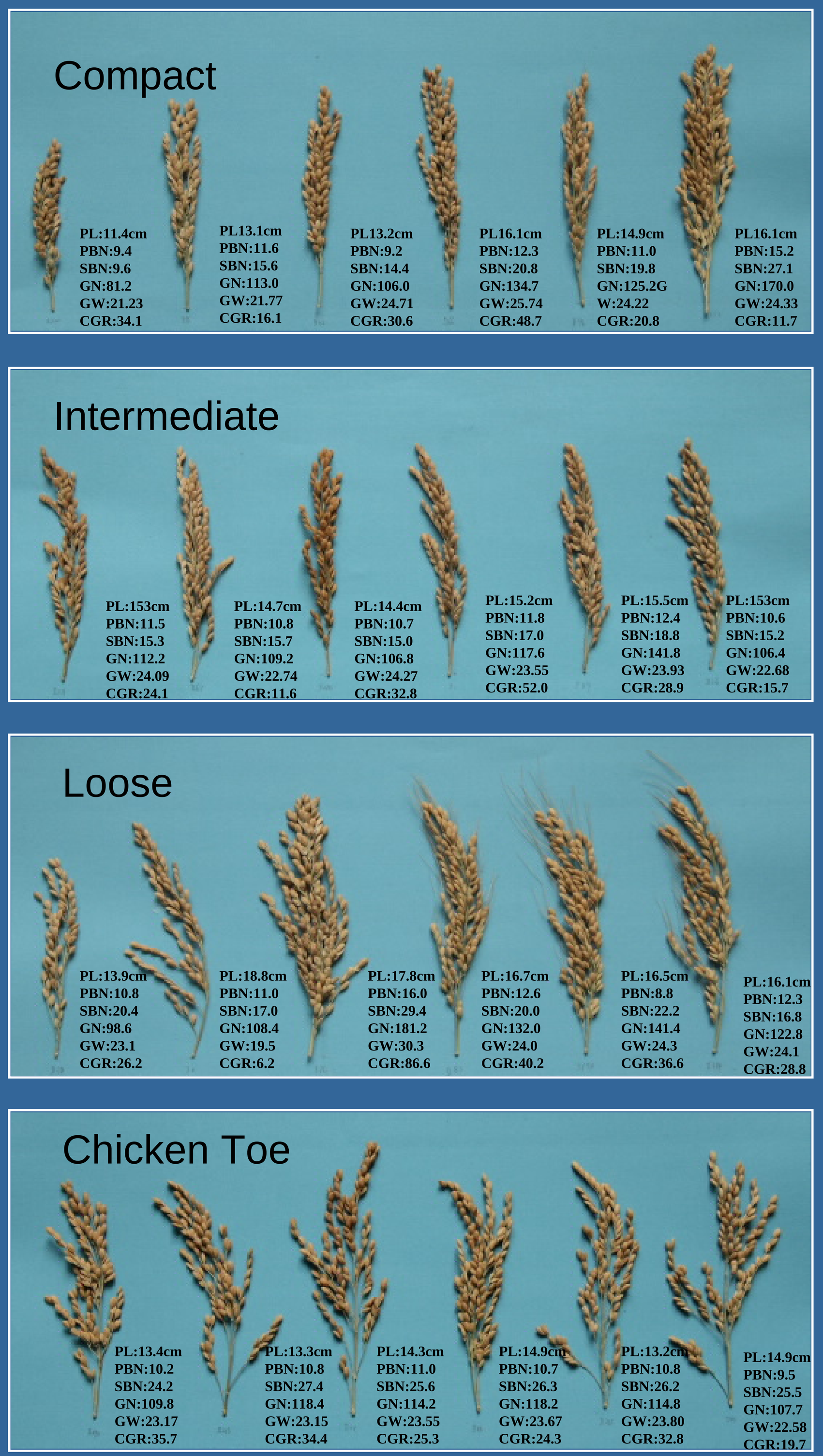

Fig. 1 Panicle characters of the 24 rice mutants.
PL, panicle length (cm); PRN, primary rachis number; SRN, secondary rachis number; GN, grain number per panicle; GW, averaged grain weight across the panicle (mg); CGR, total chalky grain rate (%), including white-belly and white-core rice grain.

RESULTS

4. By contrast, WBRK did not change much from top to bottom rachis, and the averaged value in primary rachis for top part is 24.71% whereas that for bottom rachis is 23.19%.

5. Percentage of WCRK was lower than that of WBRK, in all rachides of the four types.

6. Ratio of WCRK/WBRK did not differed significantly among four panicle types, but a marked variation existed in different positions within a panicle for the four types.

7. Generally, the order of WCRK/WBRK is top> middle > bottom, and primary rachis> secondary rachis. Sensory properties.

Panicle type	Grain position	PGN (%)	FGR (%)	GW (mg)	WCRK (%)	WBRK (%)	CGR (%)	WCRK/ WBRK (%)
Compact	TPR[b]	18.90b	96.71a	25.45a	16.75a	32.25a	49.00a	0.55a
	TSR	10.80c	94.60ab	23.04b	3.22b	21.46bc	24.58c	0.15b
	MPR	19.90ab	96.80a	24.32a	9.58ab	27.5ab	37.08b	0.34ab
	MSR	22.40a	92.98b	22.65b	2.58b	14.67cd	17.25cd	0.16b
	BPR	18.20b	96.77a	24.58a	5.17b	20.17bc	25.33c	0.23b
	BSR	9.80c	94.98ab	21.96b	1.45b	7.22d	8.66d	0.20b
	mean	16.67	95.47	23.67	6.46	20.55	26.99	0.27
	CV%	30.86	1.635	5.61	89.74	43.45	53.07	56.14
Intermediate	TPR	19.50a	96.82ab	24.39a	24.00a	20.83ab	44.83a	1.30a
	TSR	11.50b	96.67ab	23.14b	12.50b	15.83bc	28.33bc	0.95ab
	MPR	19.70a	97.06a	24.65a	13.75b	21.83a	35.58ab	0.75ab
	MSR	21.20a	96.48ab	22.69c	5.08bc	14.33c	19.42cd	0.40b
	BPR	19.10a	96.89ab	24.38a	9.25bc	16.92abc	24.38bc	0.63b
	BSR	9.00b	94.03b	22.03d	2.40c	8.32d	10.72d	0.34b
	mean	16.67	96.32	23.54	11.16	16.34	27.51	0.73
	CV%	30.50	1.19	4.58	68.31	29.88	43.48	49.30
Loose	TPR	17.50b	95.59ab	25.21a	32.50a	23.58ab	56.08a	1.45a
	TSR	11.60c	92.61ab	23.34b	12.08bc	17.92bc	35.08bc	0.79bc
	MPR	18.50b	96.65a	25.13a	20.42b	24.83a	45.25ab	0.85b
	MSR	23.20a	92.11b	22.92b	8.08c	16.17c	28.92c	0.35bc
	BPR	18.00b	94.91ab	25.16a	9.33c	25.42a	34.75bc	0.31bc
	BSR	11.20c	92.34ab	23.49b	5.00c	16.08c	24.33c	0.23c
	mean	16.67	94.03	24.2	14.57	20.67	37.40	0.66
	CV%	27.37	2.05	4.39	70.21	21.34	30.85	70.08
Chicken toe	TPR	13.00b	98.36a	24.39a	21.17a	22.17bc	43.33a	1.22a
	TSR	24.20a	96.10b	22.38b	5.67bc	19.75cd	25.42c	0.31b
	MPR	11.90b	95.72b	24.68a	12.08b	28.08ab	40.17ab	0.54b
	MSR	24.60a	96.07b	22.18b	2.17c	15.83de	18.00d	0.15b
	BPR	12.10b	96.28b	24.53a	3.92c	30.25a	34.17b	0.12b
	BSR	14.20b	94.65b	21.76c	0.50c	10.58e	11.08d	0.04b
	mean	16.67	96.20	23.32	7.59	21.11	28.69	0.40
	CV%	36.28	1.26	5.78	102.35	35.06	44.39	111.07

Chart 1 Positional variations in percentage of grain number to total grains (PGN), filled grain rate (FGR), grain weight (GW), rate of white-belly rice kernel (WBRK), white-core rice kernel (WCRK), and total chalky grain rate (CGR), and the ratio of WCRK/WBRK for the four panicle types

DISCUSSION

☐White-core grains have chalkiness in the centre of the endosperm, but white-belly grains have chalkiness in the peripheral part of the endosperm. Considering that starch is actively accumulated around the centre of the endosperm from early to middle stages and at the periphery at the late stage, the differences in the location of chalkiness indicate the different responses of these two types of chalkiness to grain position within panicle.

☐The current study clearly shows marked differences between the occurrence of WBRK and WCRK regarding the positional variation across panicle. Occurrence of these two types of chalky grain follows the similar pattern, with the order of top middle bottom. However, WCRK demonstrated a more dramatic drop from the top to bottom rachis than WBRK does

☐Ratio of WCRK/WBRK was calculated to measure the relative occurrence between the two chalkiness types. Our results revealed differences in WCRK/WBRK among grains within a panicle, with the top and primary rachides having higher values, suggesting that WCRK occurred much more willingly than WCRK on top or primary rachis.

☐These results indicate the different mechanisms between WBRK and WCRK with regard to position variation within panicle. Our lab are investigating its physiological foundation as well as the effect of agronomical practice especially nitrogen topdressing at panicle initiation stage which has substantial effect on panicle morphology.

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