Wheat Inf. Serv. 102, 2006. www.shigen.nig.ac.jp/ewis

Wheat Information Service

Electronic Newsletter for Wheat Researchers

No. 102

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Research Information

Biochemical estimation of β-carotene in Indian durum varieties

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Durum wheat is highly valued for pasta making in many parts of the world due to its attractive bright appearance which is caused by two kinds of pigments, namely xanthophylls and carotenoids. Durum wheat normally has higher pigment content than other wheat because of the presence of higher amount of xanthophylls and carotenoids (Dick and Matsuo, 1988). Among carotenoids, β-carotene is important for pasta quality and nutrition. It acts as preservative and is a precursor of vitamin-A.

There are few reports on biochemical estimation of β-carotene in wheat. Goulden *et al.* (1934) studied carotenoid in a series of hybrid wheat and a group of standard varieties of hexaploid wheat using AACC methods. Markley (1937) estimated carotenoid pigment in individual plants of *Triticum vulgare* and *Triticum durum* to study the variability using standardized Evelyn photometric colorimeter and the range of carotenoid content was found to be 2.09 ppm to 3.74 ppm. Zechmeister and Cholnoky (1940) reported carotenoids in Hungarian wheat flour to detect the nature of pigment. Lacroix and Lier (1975) documented carotenoids in durum wheat variety Hercules at different developmental stages during two growing seasons. Lepage and Sims (1968) evaluated carotenoids in two varieties of wheat, Mindum (durum) and Thatcher (hard red spring) to study the chemical nature of the pigments. Taha and Sagi (1987) used seven durum wheat varieties in Hungary to reveal the effects of some intrinsic factors of semolina on macaroni colour. There is no report of biochemical analysis of pigments on Indian durum wheat varieties. Prior knowledge of β-carotene content in commonly used wheat breeding lines help breeders to design their breeding program. There is no such comprehensive report on evaluation of common Indian durum wheat varieties for β-carotene. The present work was undertaken to evaluate commonly used Indian durum wheat varieties with respect to β-carotene content following approved AACC method (14-50, 1995) and to compare its content in rainfed and irrigated condition.

Fifty Indian durum varieties (Table 1) have been selected to evaluate β-carotene content. The varieties were grown in two successive growing seasons of 1994-95 and 1995-96 both under rainfed and irrigated conditions at Hol, Pune using randomized block design with three replications.

β-carotene was estimated following approved AACC (14-50, 1995) method as described below. Eight gram flour was taken in 150 ml glass stoppered Erlenmeyer flask and 40 ml water saturated butanol (WSB) was added. The contents of the flasks were mixed vigorously for 1 minute and kept overnight (16-18 hrs) at room temperature under dark for complete extraction of β-carotene. Next day, the contents were shaken again and filtered completely through the Whatman no.1 filter paper into a 100 ml volumetric flask. The optical density of the clear filtrate was measured at 440 nm using HITACHI U-3210 spectrophotometer. Pure WSB was used as blank. The β-carotene content was calculated from calibration curve from known amount of b-carotene as discussed below and expressed as parts per million (ppm). Standard solution of β-carotene (Sigma) was prepared in water-saturated butanol (WSB) at the concentration of 5μg/ml. WSB is prepared by mixing n-butanol with distilled water in 8:2 ratios. Calibration curve is made from known amounts of pure β-carotene from 0.25μg/ml to 1.5μg/ml which are prepared after suitable dilutions of original stock with WSB in calibrated 10 ml volumetric flasks (from 0.5 ml to 3 ml of standard solution in 10 ml). Absorbance of each dilution is measured and a calibration curve is established. β-carotene content of unknown samples is calculated from standard curve.

The β-carotene content (mean of three replications)

Table 1. Indian durum wheat varieties used for β-carotene estimation.

Variety	Pedigree	Variety	Pedigree	Variety	Pedigree
A-1	Landrace	Bijapur 370-4	Landrace	L.Y.Dharwad	Landrace
A-1-8-1	Landrace	Bijapur 487-2	Landrace	Local from Navalgunda	Landrace
A-206	Landrace	Chandur Biswa7	Landrace	MACS-1967	Gulab/CPAN1471
A-624	Landrace	Dasarkhed-1	Landrace	MACS-9	N59(GajaxMotia) x F185(POL)
A-739	Landrace	Dasarkhed-2	Landrace	Malvi Local	Landrace
A-O-90	Landrace	Datala-5	Landrace	Motia	Landrace
Bansi 102	Landrace	Datala-6	Landrace	Narsingarh Local	Landrace
Bansi 162	Landrace	Ekdania 69	Landrace	NI-146	Gaza/Baz 23
Bansi 207-3	Landrace	Gulab	Landrace	PDW-233	YAV'S' x TEN'S'
Bansi-218	Landrace	Haura-6	Landrace	Raj 1555	CIT/Raj-911
Bansi-288-18	Landrace	Jay	Motia/KPH(DM)	Raj-6496	CHAMS-3(Selection from CIMMYT)
Bansi-290	Landrace	JNK-4W-184	Released var.	U.Progeny 6	Landrace
Baxi 1-1-2	Landrace	Kathia-21	Landrace	U.Progeny 9	Landrace
Baxi 6-1-1	Landrace	Kathia-25	Landrace	Vidarbha Local	Landrace
Bhalegaon-3	Landrace	L.G.Vidarbha (NFMT)	Landrace	Vijay	Natural cross of Motia/KPH(DM)
Bhalegaon-4	Landrace	L.G.Vidarbha	Landrace	Vishram	Released var.(Local selection)
Bijaga Yellow	Mysore local/Gaza	L.R.Dharwad	Landrace		

in Indian durum varieties is presented in Table 2. Enough seeds were not available for all 50 varieties in both the growing seasons. Therefore, data were available for 29 varieties during 1994-95 and 48 varieties during 1995-96 both for rainfed (RF) and irrigated (IR) conditions. A wide range of variation in β-carotene was observed in Indian durum wheat varieties grown both in rainfed (RF) and irrigated (RI) conditions in both the years. The β-carotene content in the varieties grown during 1994-95 ranged from 2.92 to 5.82 ppm (RF) and 2.73 to 5.89 ppm (IR) whereas the range was 2.97 to 5.95 ppm (RF) and 2.25 to 7.93 ppm (IR) among the varieties grown in 1995-96. Bhalegaon-4 and Kathia-25 showed the lowest (2.92 ppm) and highest (5.82 ppm) β-carotene varieties, respectively, among the varieties grown in 1994-95 under RF condition, where as Dasharkhed and MACS 9 showed the lowest (2.73 ppm) and highest (5.89) β-carotene, respectively grown under IR condition. Similarly in 1995-96 growing season, Datala-6 and MACS-9 showed the lowest (2.97 ppm) and highest (5.95ppm) β-carotene, respectively grown under RF condition whereas A-1 and PDW-233 showed the lowest (2.25ppm) and highest (7.93 ppm) β-carotene, respectively grown under IR condition. It is evident from Table 2 that some varieties differ in β-carotene content under irrigated and rainfed conditions. Some varieties are stable with respect to β-carotene in all the conditions, eg. Bhalegaon–4 shows low β-carotene content in both RF and IR conditions in two years. The β-carotene content is higher when a variety is grown in rainfed condition and it decreases when grown under irrigated condition for most of the varieties except few exceptions. Decrease in β-carotene content from RF to IR condition ranged from 0.8% in variety Bansi-288-18 to 45% in Kathia-25 during 1994-95 seasons whereas in 1995-96, it ranged from 1% in Kathia-21 to 48% in A-1-8-1.

Estimation of β-carotene content in Indian durum varieties has obviously great importance since durum varieties are becoming more popular day by day among Indian farmers because of their high resistance to disease, yield potentiality etc. Buyers always prefer attractive colour of semolina and pasta products. So varieties having high β-carotene content like PDW-233, Raj-6496, MACS-9 etc will be more popular and those can be used in breeding program. Development of variety with good agronomic value is always based on efficient selection method. The varieties having more than 5 ppm β-carotene content are JNK-4W-184, MACS-9, Bijapur 370-4, LR Dharwad, Raj-6496 and PDW-233. Most of the Indian durum varieties have lower β-carotene with a range of 3-6 ppm with an average of 4.5 ppm except two varieties Raj-6496 and PDW-233. These two varieties have been developed by Punjab Agricultural University, Ludhiana crossing with high β-carotene Mexican varieties. This study will enable wheat breeders in selection of parental lines for crossing in breeding program to develop high β-carotene cultivar, to study inheritance of this trait, tagging and mapping of the genes involved. Based on the result presented here three varieties with high β-carotene content viz. PDW-233. Raj-6496, MACS-9 and two varieties with low β-carotene content viz, Bhalegaon-4 and Baxi 6-1-1 were selected for crossing to study the inheritance of this trait.

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Table 2. Comparison β-carotene content (ppm) in Indian durum varieties grown under two conditions in two seasons

Variety	Rainfed ('94-'95)	Irrigated ('94-'95)	% of Δ RF to IR	Rainfed ('95-'96)	Irrigated ('95-'96)	% of Δ RF to IR
Jay	3.48	2.87	17 ↓	3.80	2.93	23↓
Dasarkhed-1	4.15	4.10	1↓	4.61	4.19	9↓
Bansi-218	3.91	3.76	4↓	4.45	3.91	12↓
Chandur Biswa7	4.70	3.37	28↓	3.96	3.33	16↓
Bansi-288-18	3.70	3.67	0.8↓	4.34	3.45	20↓
Ekdania 69	4.99	4.36	12↓	4.64	5.01	7.0↑
Baxi 6-1-1	2.96	3.47	17↑	4.00	2.89	27↓
Motia	5.15	3.98	22↓	4.55	4.09	10↓
Dasarkhed-2	4.09	2.73	33↓	3.55	4.60	13↓
Bhalegaon-4	2.92	2.78	4↓	3.35	2.47	26↓
Bijapur 487-2	4.15	4.10	4.1↓	4.09	3.92	4↓
Malvi Local	4.21	3.96	6↓	4.49	3.72	17↓
Navalgunda Local	4.78	4.46	6↓	4.42	3.19	28↓
Bansi 162	3.81	3.43	10↓	4.25	3.79	10↓
Bijapur 370-4	5.55	5.10	8↓	5.39	4.40	18↓
Vijay	3.88	3.57	8↓	3.92	3.21	18↓
Vidarbha Local	3.44	3.09	10↓	4.06	3.10	23↓
Kathia-25	5.82	4.07	45↓	4.79	4.25	11↓
A-O-90	4.23	4.13	2↓	5.20	4.67	10↓
Bansi 207-3	3.76	3.91	4↑	3.95	3.29	16↓
Haura-6	3.45	3.30	4↓	3.56	3.28	8↓
Narsingarh Local	4.34	3.85	11↓	4.57	3.52	23↓
A-739	3.55	3.56	0↓	3.8	3.88	2↑
Baxi 1-1-2	4.33	4.97	8↑	4.17	3.53	15↓
Gulab				4.46	4.22	5↓
A-1				4.35	2.25	48↓
Vishram				3.60	2.86	20↓
A-1-8-1				4.51	4.88	8↑
L.Y.Dharwad				4.38	3.81	13↓
Bansi-290				4.45	3.55	20↓
Kathia-21				4.54	4.48	1↓
L.G.Vidarbha (NFMT)				3.92	3.61	8↓
Bansi 102				4.13	3.30	20↓
L.R.Dharwad				5.12	3.39	23↓

Table 2 ***(continued)***

Datala-5		4.21	3.71	9↓
U.Progeny 6		5.21	4.69	9↓
L.G.Vidarbha		3.45	3.23	6↓
Bhalegaon-3		3.13	2.70	13↓
Datala-6		2.97	3.44	16↑
U.Progeny 9		4.75	5.00	11↑
A-624		4.71	3.73	20↓
Bijaga Yellow	2.98	3.84	3.42	11↓
Raj 1555	2.98	3.47	3.20	7↓
JNK-4W-184		5.00	4.09	21↓
NI-146		4.20	3.38	19↓
MACS-9	5.89	5.95	3.30	44↓
A-206		4.34	4.03	7↓
MACS-1967	3.46	3.84	3.12	18↓
PDW-233			7.93	
Raj-6496			6.42	

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Wheat Inf. Serv. 101: 5-25, 2006. www.shigen.nig.ac.jp/ewis

Research Information

Distribution and genetic analysis of dwarfing gene *Rht-D1b* in Chinese bread wheat cultivars and lines

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Abstract
PCR-based marker for the major semi-dwarfing gene *Rht-D1b* derived from the Japanese cultivar 'Norin 10' was used to detect 421 cultivars and lines from 8 of 10 wheat zones in China. The marker was validated by testing 9 selected cultivars. Detection of this wheat collection showed that the semi-dwarfing gene *Rht-D1b* tended to be distributed non-random in geographically divergent breeding programs. The frequency of semi-dwarfing gene *Rht-D1b* among this wheat cultivars and lines over the whole country was 43.5%. The highest *Rht-D1b* distribution frequency was 63.6% in Northern spring wheat zone and the lowest one was 13.3% in northeastern spring wheat zone. The distribution frequency of other wheat zones was 37.9% in northern winter wheat zone, 55.6% in Yellow & Huai River Facultative winter wheat zone, 32.4% in Middle & Low Yangtze Valley winter wheat zone, 33.3% in southwestern winter wheat zone, 12.5% in northwestern spring wheat zone and 25.0% in Xinjiang winter-spring wheat zone, respectively.

Introduction
The control of plant height in cereals is known to be complex because of its polygenic and subject to environmental effects. Tall wheat cultivars (*Triticum aestivum* 2n=6x=42) are more prone to lodging, particularly when grown in favorable environments, whereas semi-dwarf cultivars are shorter, less prone to lodging (Ahmad and Sorrells 2002). Reducing height has both directly improved the plant's ability to divert available resources into grain rather than straw and has also improved lodging resistance. Genes with this ability have been difficult to detect, resulting in the vast majority of the world's semi-dwarf wheat crop cultivars having their height reduction determined primarily by one of two major genes derived from the old Japanese cultivar 'Norin 10'(Worland and Sayers, 1995). Over the past half century, the height of China-grown wheat crop has been steadily reduced from over 107.9cm down to the current height of around 90cm（Xu et al. 2001）. The use of dwarfing genes to reduce plant height improve yield potential has been one of the major strategies in breeding modern, high yielding bread wheat cultivars (Gale and Youssefian 1985).

Under optical circumstances in China, *Rht-B1b* and *Rht-D1b* (new nomenclature after Borner et al. 1996) can combine height reductions of approximately 23% with similar levels of increased yield (Borner et al. 1993; Flintham et al. 1997; Wang S.H. et al. 2001). These GA-insensitive dwarfing genes are probably present in around 90% of the world's semi-dwarf wheat crop and were responsible for the worldwide green revolution in wheat cultivation (Worland et al. 1998). It is therefore of up-most importance that alternative GA-responsive dwarfing genes are studied and that where those offer potential to improving crop yields. Molecular markers should be generated to enable breeders to recognize and select for these genes in their segregating populations (Worland et al. 1998).

Ellis et al. (2002) developed PCR-based markers specific for the *Rht-B1b* and *Rht-D1b* semi-dwarfing genes in wheat and in the sense could be described as 'perfect markers'. What is more, Ellis et al. (2002) presented evidence that validates the specificity of the markers--a range of selected wheat cultivars of known *Rht* status being correctly genotyped by the markers.
In the experiments described here 421 cultivars have been detected for the semi-dwarfing genes *Rht-D1b* by using the primers. The cultivars and lines were chosen to include key cultivars in the pedigrees of modern cultivars in 8 of 10 wheat zones in China diverse national breeding programs.

Materials and methods

Plant materials

A total of 421 genotypes were used for this study. This material consists mainly of cultivars and lines of 8 of 10 wheat zones in China, which have been widely and commercially grown during the last decade and some now are still being grown. Pedigree information was kindly provided by various breeders or from Zhuang (2003). All wheat cultivars and lines along with their pedigree, breeding place, wheat zone genotype, are unlisted but the author can provide them to who need.

Template DNA preparation and PCR analysis

High-molecular-genomic DNA was extracted from leaves of 2- to 4-week-old plants grown in the growth chamber. The DNA extraction procedure was a modification of that described by Sharp et al. (1989). The genomic DNA was diluted in sterile water to a concentration of 0.02ug/ul. Primer combinations for polymerase chain reaction (PCR) conditions and PCR were fully described by Ellis et al. (2002), but PCRs were conducted with a Precision Scientific Genetic Thermal Cycler (MJ Research). Amplifications were assayed running the following program: after initial denaturing for 15 min at 95^{o}C, 38 cycles of 30 s at 94^{o}C, 30s at 63 ^{o}C, 30s at 72 ^{o}C, and a final extension step of 5 min at 72 ^{o}C. (personal communication). PCR products were separated on 2% (w/v) agarose gel at 190v. Gels were then stained with ethidium bromide (EB) and visualized and photographed under UV light.

Results and discussion

Validation of PCR markers on selected wheat cultivars

Nine of wheat cultivars and lines of unknown but Norin 10 as a check variety *Rht* genotype were selected and DNA samples from these lines were analyzed by PCR using the *Rht-B1a, Rht-B1b, Rht-D1a* and *Rht-D1b* markers for 10 repetitions, respectively. Varieties carrying dwarfing gene *Rht-B1b* gave an amplification products of expected fragments (237bp) with the *Rht-B1b* primer combination as described in detail by Ellis. At the same time these varieties didn't give an amplification products of expected fragments (237bp) with the *Rht-B1a* primer combination. This could indicate that these primer combinations were validated for the *Rht-B1a, Rht-B1b* specific. But while we detected the 421 wheat cultivars and lines, some false positives were on the agarose gels and frequency got to 14.67%, therefore we produced doubts for the *Rht-B1a, Rht-B1b* specific primers combinations. In the present paper, we didn't listed the results detected cultivars of *Rht-B1b* dwarfing gene.

The same status didn't bring forth to the *Rht-D1a* and *Rht-D1b* primer combinations either for the selected cultivars or for the 421 wheat cultivars and lines, the frequency was only less than 0.7%. Here we could say that the primer combination of *Rht-D1b* was specific to the semi-dwarfing gene *Rht-D1b* (Fig. 1 and Fig. 2).

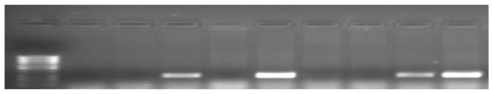

Figure 1. Validation of *Rht-D1b* gene specific STS primer with 9 wheat cultivars. M 100bp ladder, 1.Jingdong 8, 2.Xiaoyan 22, 3.Jinan 2, 4.Yangmai 4, 5.Fan 6, 6.E'en 1, 7.Henong 326, 8.Taishan 4, 9. Norin 10 (CK)

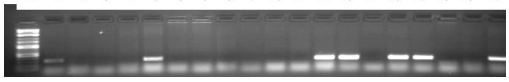

Figure 2. Electrophoresis of PCR product amplified with the STS Marker of *Rht-D1b* gene for check lines and some tested cultivars in agarose gel. M 100bp ladder, 1. Zhongyou 9843, 2. Suyin 10, 3. Xiaoyan 54, 4. Yuandong 6, 5. Yuandong 107, 6. Yuandong 971, 7. Yuandong 8585, 8. Yuandong 9428, 9. Nongda 116, 10. Nongda 123, 11. Nongda 152, 12. Nongda 3197, 13. Nongda 3213, 14. Jingdong 8, 15. Nongda 3291, 16. Nongda 3395, 17. Jingdong 10, 18. Jing 411, 19. Norin 10 (ck)

Countrywide frequency distribution of semi-dwarfing gene *Rht-D1b*

PCR-based marker analysis for the *Rht-D1b* of all of 421 wheat cultivars and lines indicated that the frequency distribution was highly different between 8 of 10 wheat zones in China. Over all 421 cultivars and lines, 183 carried *Rht-D1b* semi-dwarfing gene and frequency approximately was 43.5%. Among the 4 winter wheat zones, Yellow & Huai River Facultative winter wheat zone (YHRF WWZ) had the highest frequency of 55.6%, 12.1% more than countrywide average, while the lowest wheat zone was Middle & Low Yangtze Valley (MLYV WWZ) at a ratio of 32.4%, the other 2 wheat zones of Northern WWZ and Southwestern WWZ were 37.9% and 33.3%, respectively. Conversely among the 4 spring wheat zones, Northern SWZ had the highest frequency of 63.6%, 20.1% higher than the countrywide average, however the lowest spring wheat zone was Northeastern SWZ at a ratio of 13.3%, namely, there was only two cultivars carrying *Rht-D1b* semi-dwarfing gene. The evidences above demonstrated that the screening of varieties for *Rht-D1b* dwarfing gene tended to be non-random in geographically divergent breeding programs for each wheat zone in China. The causes that gave rise to the different frequency distribution in China's wheat zones should be: first, different dwarf resources used in wheat zones created different frequency distribution of *Rht-D1b* gene; as an example of Youbao mai wheat widely used in YHRF WWZ caused higher ratio of *Rht-D1b*; second, some wheat zones needed tall wheat cultivars and lines, and that wheat breeding is a comprehensive process, sometimes for some characters it must give up plant height as a minor character, for instance, in Northwestern SWZ.

Genetic diversity

The results of PCR amplification of 421 wheat genotypes using *Rht-D1b* specific primer pairs and the cultivar pedigrees are summarized in Table 1 which showed that the correlation between the semi-dwarfing gene *Rht-D1b* based on the specific primer combination and cultivar pedigree was highly significant. The results of the cultivar analysis with *Rht-D1b*-specific primers described above would suggest that the distribution frequency of semi-dwarfing gene *Rht-D1b* in countrywide breeding programs is more likely due to selection than chance. The main areas of distribution for the *Rht-D1b* gene are throughout Northern SWZ and throughout Yellow & YHRF WWZ.

The *Rht-D1b* gene mainly derived from two dwarf resources (Jia et al. 1992): (1) cultivars characteristic of Huixianhong and Youbaomai carrying a semi-dwarfing *Rht-D1b GA*-insensitive gene (Fig.3). (2) cultivars characteristic of Norin 10 and Sweon 86 carrying a semi-dwarfing *Rht-B1b* and *Rht-D1b GA*-insensitive genes (Fig.4). We found some cultivars and lines derived from Taigu male sterile lines also carried a *Rht-D1b GA*-insensitive gene (cultivars as Jinghe 951, Jingnong 8318, Yuandong 971, Yumai 50 and so on listed in Table 1). Therefore we categorized the dwarfing gene *Rht-D1b* credited with playing major roles in improving wheat yields into three classes: some from introduction from abroad, some from Chinese old landlaces and some from Taigu nuclear male sterile lines

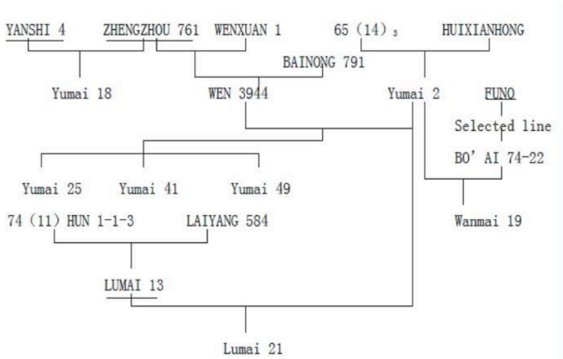

Figure 3. Pedigree and *Rht-D1b* classification of several Yellow & Huai River Facultative WWZ wheat cultivars: capital letters untested, small letters carrying a *Rht-D1b* dwarfing gene, capital letters underlined have their pedigrees given elsewhere.

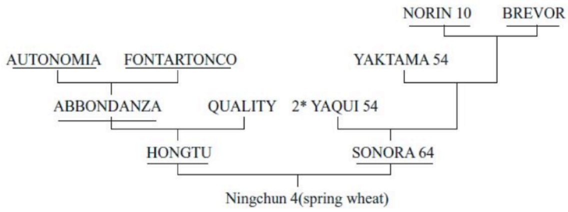

Figure 4. Pedigree and *Rht-D1b* classification of Northwestern spring wheat zone spring wheat cultivar—Ningchun 4

Conclusions

Genetic analysis of 421 cultivars and lines and 10 repetitions for the selected cultivars validation and the above discussion amply demonstrated the utility of the marker based on the PCR could be used not only as a diagnostic marker for the dwarfing gene *Rht-D1b* which, until now, has been difficult to detect in breeding populations but also to study in genetic analysis. Therefore, we could conclude that on the basis of the 'perfect marker', diverse parents could be selected. With the availability of a rich collection of cultivars and lines recently made available through collaborative efforts and individual efforts elsewhere, this would certainly become the markers of choice in the future for a variety of studies and molecular-assisted selection.

Acknowledgements

We wish to express gratitude to Dr. David Bonnett for his providing PCR reaction condition. We would like to thank my teachers and classmates who acted as reviewers and advisors.

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Table 1. Wheat cultivars and lines, their pedigrees, breeding place, wheat zones and genotypes

Cultivar/line	Pedigree	Wheat Zone	Breeding Place	Genotype
97 Dong 96	88 Dong 26/Anyang 106-1	Northern WWZ	Chinese AAS	*Rht-D1b*
Beijing 10	Huabei 672/Xinshi 14//Soviet Zaoshu 1/Huabei 672	Northern WWZ	Chinese AAS	
Beinong 66	Beinong 80-4064/Jing 411	Northern WWZ	Beijing Agricultural College	*Rht-D1b*
CA8686	Fenkang 4/Baiquan 5-Youmangbai 4/Youmangbai 4-Lovrin 10	Northern WWZ	Chinese AAS	*Rht-D1b*
CA9410	Norman/Changfeng 4//Jing 411	Northern WWZ	Chinese AAS	
CA9553	CA8695/C39//Jing 411	Northern WWZ	Chinese AAS	
CA9632	Linfendasui/CA8686	Northern WWZ	Chinese AAS	*Rht-D1b*
CA9640	CA8695/C39//Jing 411	Northern WWZ	Chinese AAS	
CA9641	CA8695/C39//Jing 411	Northern WWZ	Chinese AAS	
CA9648	CA8695/C39//Jing 411	Northern WWZ	Chinese AAS	
CA9719	Guinong 11-2/Jing 411	Northern WWZ	Chinese AAS	
CA9722	Guinong 11-2/Jing 411	Northern WWZ	Chinese AAS	
Dongfanghong 3	Line selected from Nongda 45	Northern WWZ	Chinese AU	
Dongfeng 611	Lumai 7/BT811	Northern WWZ	Chinese AAS	
Dongfeng 9801	Ji 5418/Yun 8524	Northern WWZ	Chinese AAS	
Dongfeng 9817	Lumai 7/BT811	Northern WWZ	Chinese AAS	
Fengkang 2	Youmangbai 4/Lovrin 10	Northern WWZ	Chinese AAS	
Fengkang 8	Youmangbai 7/Lovrin 10	Northern WWZ	Chinese AAS	
Gaoyou 503	78506-2-4-6/845504(78506/Zaoyou 504)	Northern WWZ	Chinese Academy of Sciences (CAS)	*Rht-D1b*
Jing 411	Fengkai 2/Changfeng 1	Northern WWZ	Beijing Seed Company	
Jing 837	Youmanghong 7/Lovrin 10/3/Jingshuang 6//Shanqianmai//Jingshuang 3	Northern WWZ	Beijing Seed Company	
Jing 841	Beijing 18/Fengkang 4//Nongda 139	Northern WWZ	Beijing Seed Company	
Jing 9428	Jing 411/Dunbanmai (Germany)	Northern WWZ	Beijing Seed Company	
Jingdong 6	Jingnong 79-1/Nongdadai 177-143	Northern WWZ	Beijing AAS	
Jingdong 8	Beijing 8//Heine Hevde/Orofen	Northern WWZ	Beijing AAS	

Table 1. *(continued)*

Jingdong 10	Selected from nuclear sterile lines	Northern WWZ	Beijing AAS	
Jinghe 951	Selected from nuclear sterile lines	Northern WWZ	Beijing AAS	*Rht-D1b*
Jingnong 8318	Taigu nuclear nuclear sterile lines /Jingnong 83-91	Northern WWZ	Beijing AAS	*Rht-D1b*
Jingnong 97-96	Taigu nuclear nuclear sterile lines /Jingnong 83-91	Northern WWZ	Beijing AAS	
Jingnong 98-100	Linfen 536/6584//Shout Population//830022	Northern WWZ	Beijing AAS	
Jinnong 207	Unknown	Northern WWZ	Shanxi AU	
Jinnong 215	Unknown	Northern WWZ	Shanxi AU	
Jinnong 216	Unknown	Northern WWZ	Shanxi AU	*Rht-D1b*
Jinnong 218	Unknown	Northern WWZ	Shanxi AU	*Rht-D1b*
Jingwang 10	Jingshuang 2/Lovrin 13	Northern WWZ	Beijing Dongbeiwang Farm	
Liken 2	Selected from Zhongzuo 8131-1	Northern WWZ	Beijing AAS	
Lunhui 201	Selected from nuclear sterile lines	Northern WWZ	Beijing AAS	
Nongda 116	Annong 84-106/Nongda 93	Northern WWZ	Chinese AU	*Rht-D1b*
Nongda 123	865039/Changfeng 3//86 Zhong 195	Northern WWZ	Chinese AU	*Rht-D1b*
Nongda 139	Nongda 183/Vi'er//30983/Yanda 1817	Northern WWZ	Chinese AU	*Rht-D1b*
Nongda 152	Linfeng 5064/Sha'an 011	Northern WWZ	Chinese AU	
Nongda 3197	Nongda 3338/91170	Northern WWZ	Chinese AU	*Rht-D1b*
Nongda 3213	Nongda 3205/Nongda 3214	Northern WWZ	Chinese AU	*Rht-D1b*
Nongda 3214	Nongda 3338/S180	Northern WWZ	Chinese AU	*Rht-D1b*
Nongda 3395	Nongda 3338/S180	Northern WWZ	Chinese AU	*Rht-D1b*
Nongda 3291	Nongda 3338/S180	Northern WWZ	Chinese AU	*Rht-D1b*
Xiaoyan 54	Selected from Xiaoyan 6	Northern WWZ	CAS	
Youxuan 9	Line derived from Zhongzuo 8131-1	Northern WWZ	Chinese AAS	
Youxuan 14	Line derived from Zhongzuo 8131-1	Northern WWZ	Chinese AAS	
Yuandong 6	((Yuandong 94//22-4) Y14) 2-8	Northern WWZ	Chinese AAS	
Yuandong 107	Selected from nuclear sterile lines	Northern WWZ	Chinese AAS	*Rht-D1b*

Table 1. *(continued)*

Yuandong 971	Selected from nuclear sterile lines	Northern WWZ	Chinese AAS	*Rht-D1b*
Yuandong 8585	Selected from nuclear sterile lines	Northern WWZ	Chinese AAS	
Yuandong 9428	Selected from nuclear sterile lines	Northern WWZ	Chinese AAS	
Zhongmai 9	Siyang 936/83 Jian 25	Northern WWZ	Chinese AAS	*Rht-D1b*
Zhongmai 16	Yan 1931/3/50381-94//Yanda 72-629/4628-2-3	Northern WWZ	Chinese AAS	*Rht-D1b*
Zhongyou 8	Selected from Zhengzhou 8603	Northern WWZ	Chinese AAS	
Zhongyou 14	Line derived from Zhongzuo 8131-1	Northern WWZ	Chinese AAS	
Zhongyou 16	Line derived from Zhongzuo 8131-1	Northern WWZ	Chinese AAS	
Zhongyou 9507	Line derived from Zhongzuo 8131-1	Northern WWZ	Chinese AAS	
Zhongyou 9507(short)	Line derived from Zhongzuo 8131-1	Northern WWZ	Chinese AAS	*Rht-D1b*
Zhongyou 9701	Line derived from Zhongyou 9507	Northern WWZ	Chinese AAS	*Rht-D1b*
Zhongyou 9814	Nongda 95/Zhongyou 16//Zhongyou 16-29	Northern WWZ	Chinese AAS	*Rht-D1b*
Zhongyou 9843	Nongda 95/Zhongyou 16//Zhongyou 16-29	Northern WWZ	Chinese AAS	*Rht-D1b*
Zhongyou 9844	Nongda 95/Zhongyou 16//Zhongyou 16-29	Northern WWZ	Chinese AAS	
Zhongzuo 8131-1	Jing 771/Zhong 7606//Yin 1053	Northern WWZ	Chinese AAS	
00-52090	Zhoumai 9/92 Zhong 214	Yellow & Huai River Facultative WWZ(YHRF WWZ)	Chinese Cotton Institute	*Rht-D1b*
9(54)	Zhengzhou 8329/Zhoumai 9	YHRF WWZ	Xuzhou IAS of Jiangsu	*Rht-D1b*
96 C 1	Lumai 14//(77(2) Long spike 16) F3	YHRF WWZ	Hebei AAS	*Rht-D1b*
99G46	Unknown	YHRF WWZ	Shanxi AAS	*Rht-D1b*
99G66	Unknown	YHRF WWZ	Shanxi AAS	*Rht-D1b*
99G80	Unknown	YHRF WWZ	Shanxi AAS	*Rht-D1b*
01 Zhong 427	Lumai 14/94 Pin 201(Yuncheng 8524/86 Zhong 15)	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
01 Zhong 460	Yan 1604/86S1002	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
01 Zhong 462	Aizao 781/Shannong 215953	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*

Table 1. *(continued)*

85 Zhong 33	Orofen/Beijing 8//LK338/730-04	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
89 Zhong 448	Yuncheng 8524/86 Zhong 15	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
93 Zhong 6(37)	Yuncheng 8524/86 Zhong 15	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
98 Zhong 18	Lumai 5/Santerno	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
98 Zhong 33	Sanerao/Lumai 5	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
99 Zhong 15	85 Zhong 33/Yuncheng 90－4	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Aizao 410	[(C39/Northwest 78(6)9-2)/(FR81-3/Aizao 781-4)]//Aizao 781-4	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Baiyu 149	Caishibumai/Xingxuan 1	YHRF WWZ	Shandong AAS	
Canghe 030	Selected from Taigu nuclear sterile lines	YHRF WWZ	Cangzhou IAS of Hebei	
Fengyou 6	Zhou 8846/Bian 8579-2	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Fengyou 7	Xiaoyan 6/NPFP/Fan 1(Ta2469 selected population)	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Gaocheng8901	7297/Xingfumai//Linzhangmai	YHRF WWZ	Hebei AAS	
Han 3475	Peixian 30421/Han 4162	YHRF WWZ	Handan AAS of Hebei	*Rht-D1b*
Han 4564	88-6012/Shi 5144	YHRF WWZ	Handan AAS of Hebei	*Rht-D1b*
Han 4589	Han 4032/85 Zhong 47	YHRF WWZ	Handan AAS of Hebei	*Rht-D1b*
Han 4599	Han 4032/85 Zhong 47	YHRF WWZ	Handan AAS of Hebei	*Rht-D1b*
Han 5316	Han 7808/CA8059//85 Zhong 47	YHRF WWZ	Handan AAS of Hebei	*Rht-D1b*
Han 6172	Han 4032/Zhongyin 1	YHRF WWZ	Handan AAS of Hebei	*Rht-D1b*
Henong 341	03308/79-2060	YHRF WWZ	Hebei AU	*Rht-D1b*
Henong 1121	Anyang 10/Aifeng 1//75(89)	YHRF WWZ	Hebei AU	
Henong 1150	Unknown	YHRF WWZ	Hebei AU	
Henong 1168	Unknown	YHRF WWZ	Hebei AU	
Henong 2552	Unknown	YHRF WWZ	Hebei AU	
Huixianhong	Huixian landrace	YHRF WWZ	Henan Huixian	*Rht-D1b*
HS97-1	84 Plus 79/Sha'an 229//Mianyang 8424/3/Shi 4185	YHRF WWZ	Hebei AAS	
HS97-10	Jimai 26/Gaomai 8//Punong 3665/pin 16	YHRF WWZ	Hebei AAS	

Table 1. *(continued)*

Ji 5099	Lovrin 10/(Huadong 6/Jili)	YHRF WWZ	Hebei AAS	*Rht-D1b*
Ji 5219	Lovrin 10/Huadong 6	YHRF WWZ	Hebei AAS	*Rht-D1b*
Jimai 24	Anyang 10/Aifeng 1//75(89)	YHRF WWZ	Hebei AAS	*Rht-D1b*
jimai 38	Zhi 4001/Shi 4212-1	YHRF WWZ	Hebei AAS	
Jinan 16	Tai Radiant 63/775-1	YHRF WWZ	Shandong AAS	*Rht-D1b*
Jinan 17	Linfen 5064/Lumai 13	YHRF WWZ	Shandong AAS	*Rht-D1b*
Jining 936098	Yan 1934/82(47046) F1//(Liao 85-1/2114)F1	YHRF WWZ	Shandong AAS	
Jinmai 45	Saric/Linfen 3029/3/74100//Youbao -036/Xiaoyan 759	YHRF WWZ	Shanxi AAS	
Jinmai 50	Pingyang 181/Qingfeng 1	YHRF WWZ	Shanxi AAS	
Jinmai 60	Linfen 87-6015/Yun 8524	YHRF WWZ	Shanxi AAS	
Jinmai 61	Yumai 13/Lumai 14	YHRF WWZ	Shanxi AAS	*Rht-D1b*
Jinmai 67	Yi 79-2060/Fengkang 7	YHRF WWZ	Shanxi AAS	
Ji-Z76	Unknown	YHRF WWZ	Hebei AAS	
Kaifeng 2	(Zhengzhou 975) Zhoumai 8846/Bian 8579-2	YHRF WWZ	Kaifeng IAS of Henan	
Lankao 411	893B25/Lankao 906	YHRF WWZ	Lankao IAS of Henan	
Lankao 906	Rye MZAbondBatR/Yumai 2	YHRF WWZ	Lankao IAS of Henan	
Lankao 906-4	Line from (84) 184 Rye MZALEONDBATR/Yumai 2//90	YHRF WWZ	Lankao IAS of Henan	*Rht-D1b*
Lankao No.8	Rye 84(184)/90	YHRF WWZ	Lankao IAS of Henan	
Lankao No. 24	Rye/Bread wheat 1B/1R	YHRF WWZ	Lankao IAS of Henan	
Linfen 125	Unknown	YHRF WWZ	Shanxi AAS	*Rht-D1b*
Linfen 127	Northwest Harvest/St 2422/464//Sha'an 7587/Mintor	YHRF WWZ	Shanxi AAS	
Linfen 137	Linfen 5084/(St 2422/464/Xiaoyan 96)	YHRF WWZ	Shanxi AAS	
Linfen 138	Linfen 5064/(Youbaomai/St 2422/464)	YHRF WWZ	Shanxi AAS	
Linfen 139	Linfen 5064/Taiyuan 163	YHRF WWZ	Shanxi AAS	
Linhan 205	Shannong 2005/Chzngwu 131	YHRF WWZ	Shanxi AAS	
Linhan 614	Zhong 898/Yun 8524//Lumai 14	YHRF WWZ	Shanxi AAS	

Table 1. *(continued)*

Linhan 619	Zhong 898/Yun 8524//Lumai 14	YHRF WWZ	Shanxi AAS	
Linhan 917	Luhan 1293/B35-6-12	YHRF WWZ	Shanxi AAS	*Rht-D1b*
Linyou 1583	Linyou 21/Sha'anyou 225	YHRF WWZ	Shanxi AAS	
Lu 95(6) 161	86-45a/Ji 83-416699//Baofeng 7228	YHRF WWZ	Shandong AAS	*Rht-D1b*
Lumai 21	Lumai 13/Yumai 2	YHRF WWZ	Shandong AAS	*Rht-D1b*
Lumai 22	Mutant plant from Taishan 2/Yannong 15//Jinghua 1	YHRF WWZ	Shandong AAS	
Lumai 23	Lumai 8/Dali'ai	YHRF WWZ	Shandong AAS	
Luohan 2	Luoyang 78(111) short/Jinmai 33	YHRF WWZ	Luoyang IAS of Henan	
Neixiang 184	Mianyang 84-27/Neixiang 82C6//Yumai 17	YHRF WWZ	Neixiang IAS of Henan	
Neixiang 188	Mianyang 84-27/Neixiang 82C6//Yumai 17	YHRF WWZ	Neixiang IAS of Henan	
Neixiang 991	87C27/Zhengzhou 84115//Zhengzhou 891(Yumai 13)	YHRF WWZ	Neixiang IAS of Henan	*Rht-D1b*
PH 1521	Lumai 16/PH85-21	YHRF WWZ	Shandong AU	
PH 82-2-2	Mutant plant from Xiaoyan 6	YHRF WWZ	Shandong AU	
PH 85-1-1	PH85-115-2// 79401 /Lumai 11	YHRF WWZ	Shandong AU	
PH 85-16	Line selected from PH82-8	YHRF WWZ	Shandong AU	
Puyang 8441	Luoyang 7602/Yumai 2	YHRF WWZ	Puyang IAS of Henan	*Rht-D1b*
Puyou 9175	Kai 79-2/Xinong 80(6)-10	YHRF WWZ	Puyang IAS of Henan	*Rht-D1b*
RF-1	Line selected from Siyang936	YHRF WWZ	Huaiyin IAS of Jiangsu	
Sha'an 150	Zhongsi/681/3/Bainong 3217/Zhong 5//Bainong 3217/4/Xiaoyan 6	YHRF WWZ	Sha'anxi AAS	
Sha'an 160	Sha'an 253/Sha'an 167-6-4	YHRF WWZ	Sha'anxi AAS	
Sha'an 229	Sha'an 7853//TB902/Xiaoyan 6(Gaojiasuo /6811(2) 2-2/TB902/7014R0-1)	YHRF WWZ	Sha'anxi AAS	
Sha'an 253	Sha'an 229/Sha'an 213	YHRF WWZ	Sha'anxi AAS	
Sha'an 354	Sha'an 213/Sha'an 167-6-4	YHRF WWZ	Sha'anxi AAS	
Sha'an 512	Sha'an 150/Sha'an 354	YHRF WWZ	Sha'anxi AAS	
Sha'an 623	Sha'an 213/Sha'an 167	YHRF WWZ	Sha'anxi AAS	
Sha'an 715	Sha'an 354/Yanmai 8911	YHRF WWZ	Sha'anxi AAS	

Table 1. *(continued)*

Sha'an 898-33	Chinese Spring 5B Monosome/Rye/CS	YHRF WWZ	Sha'anxi AAS	
Sha'an 9314-56	Sha'an 354/8858-7	YHRF WWZ	Sha'anxi AAS	
Sha'an 9627-14-10	Sha'an 354/Yanmai 8911	YHRF WWZ	Sha'anxi AAS	
Sha'an 93302	Sha'an 213/Sha'an 167	YHRF WWZ	Sha'anxi AAS	
Sha'an 302518	Sha'an 213/Sha'an 167-6-4	YHRF WWZ	Sha'anxi AAS	
Sha'anyou 225	Xiaoyan 6/NS2761	YHRF WWZ	Sha'anxi AAS	
Sha'anzi 1869	Sha’an 354/Sha’anmai 898	YHRF WWZ	Sha'anxi AAS	
Shandong 924402	85-5072/865139//Yan 1934	YHRF WWZ	Shandong AAS	*Rht-D1b*
Shandong 928802	84(4)021/78170-6-1-1	YHRF WWZ	Shandong AAS	*Rht-D1b*
Shandong 935031	Lumai 13/Linfen 5064	YHRF WWZ	Shandong AAS	*Rht-D1b*
Shandong 94(6)006	Yan 1937/86 Ai 1	YHRF WWZ	Shandong AAS	*Rht-D1b*
Shandong 955159	Lumai 14/Lu 884187	YHRF WWZ	Shandong AAS	*Rht-D1b*
Shandong height	Chuan 35050/Shannong 863(Youbao/Orofen/Aimengniu)	YHRF WWZ	Shandong AU	
Shandong G-02	Chuan 35050/Shannong 863	YHRF WWZ	Shandong AU	*Rht-D1b*
Shandong G-03	Chuan 35050/Shannong 863	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 617	110633/Yin 9011302	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 664	520627/Nannong 871	YHRF WWZ	Shandong AU	
Shannong 863	921995-2(411206/412446) / Yuan 8443	YHRF WWZ	Shandong AU	
Shannong 1355	Siouyland / Yan 881414	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 2013	Siouyland / Yan 881414	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 60182	521248 / BQ2// 921995-2	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 413863	87P116/Guinong 87-6//910637/3/Yuan 8443	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 924122	Linfen 5064/Lumai 13	YHRF WWZ	Shandong AU	*Rht-D1b*

Table 1. *(continued)*

Shannong 954072	Lu 895392/Lu 84187	YHRF WWZ	Shandong AU	
Shannong 95(6) 161	86-45a/Ji 83-416699//Baofeng 7228	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 975429	Lu 895392/Lu 924151	YHRF WWZ	Shandong AU	*Rht-D1b*
Shannong 990525	V8165/ Sha'an 229	YHRF WWZ	Shandong AU	
Wen 8	394A/Siyang 1883	YHRF WWZ	Wenxian IAS of Henan	*Rht-D1b*
Wen 2540	Bainong 791//Wenxuan 1/Zhengzhou 761/3/Yumai 2	YHRF WWZ	Wenxian IAS of Henan	*Rht-D1b*
Xiaoyan 6	St2422/464/Xiaoyan 96	YHRF WWZ	*Northwest Botonical Institute (NBI) of CAS*	
Xiaoyan 22	Xiaoyan 6/775-1//Xiaoyan 107	YHRF WWZ	NBI of CAS	
Xiaoyan 143	87C332/Xiaoyan 135	YHRF WWZ	NBI of CAS	
Xiaoyan 921	Line from Xiaoyan 246	YHRF WWZ	NBI of CAS	
Xin 9178	Yuanyuanchangbai//C5/3577F3	YHRF WWZ	Xinxiang IAS of Henan	*Rht-D1b*
Xinmai 9	Baiquan 3047-3/Neixiang 82C6	YHRF WWZ	Xinxiang IAS of Henan	*Rht-D1b*
Xinmai 11	Zhou 8826/Xinxiang 3577	YHRF WWZ	Xinxiang IAS of Henan	
Xinong 953	Xinong 918/Zhi 87-135	YHRF WWZ	Northwest AU	*Rht-D1b*
Xinong 1718	Xinong 242//84G6/Sha'an 167	YHRF WWZ	Northwest AU	
Xinong 2208	Sha'an 229//Sha'an 213/Xinong 8623	YHRF WWZ	Northwest AU	
Xinong 2611	Xinong 881/Sha'an 229	YHRF WWZ	Northwest AU	
Xinong N9209-3	V2/Xiaoyan 6	YHRF WWZ	Northwest AU	*Rht-D1b*
Xinong 291	xiaoyan 5/Rye WOH45	YHRF WWZ	Northwest AU	
Xinong 336	Sha'an 229/88(1)F4	YHRF WWZ	Northwest AU	*Rht-D1b*
Xinong 962	Anther cultrue callus from Sha'anyou 225	YHRF WWZ	Northwest AU	
Xinong981	Anther cultrue callus from Sha'anyou 225	YHRF WWZ	Northwest AU	
Xinong 1163-20	84 plus 79/Xinong 1376	YHRF WWZ	Northwest AU	*Rht-D1b*
Xinong 6426	229/3/84(14) 43/83(2) 3-3/Xinong 65/Xiaoyan 6	YHRF WWZ	Northwest AU	*Rht-D1b*
Xinong 8925-13	Unknown	YHRF WWZ	Northwest AU	

Table 1. *(continued)*

Xinong 12208019	Sha'an 229//Sha'an 213/Xinong 8623	YHRF WWZ	Northwest AU	
Xuzhou 25	Xuzhou 79904-13-2-2/Bainong 792	YHRF WWZ	Xuzhou IAS of Jiangsu	*Rht-D1b*
Yantai 239	Yan 8803-239//Yan 1602 / CA84104	YHRF WWZ	Yantai AAS of Shandong	
Yantai 475	Sha'an 229/Anmai 1	YHRF WWZ	Yantai AAS of Shandong	*Rht-D1b*
Yantai 2801	Yumai 2/79 Dong 52//Lumai 14	YHRF WWZ	Yantai AAS of Shandong	*Rht-D1b*
Yanfu 188	(Zhong 22/Xingmai 7721) F3//Lumai 7 r-ray Radiated	YHRF WWZ	Yantai AAS of Shandong	*Rht-D1b*
Yannong 15	57 selected from Youbao/St2422/464	YHRF WWZ	Yantai AAS of Shandong	
Yannong 18	Zhong 144/Zai 5241//Xiaoheimai Yi 8	YHRF WWZ	Yantai AAS of Shandong	*Rht-D1b*
Yannong 19	Yan 1933/Sha'an 82-29	YHRF WWZ	Yantai AAS of Shandong	*Rht-D1b*
Yanyou 361	Yan 1933/Sha'an 82-29	YHRF WWZ	Yantai AAS of Shandong	*Rht-D1b*
Yanzhan 4110	C39/Northwest 78(6)9-2//FR81-3/Aizao 781-4/3/Aizao 781-4	YHRF WWZ	Yanshi IAS of henan	
Yumai 2	65(14)3/Huixianhong	YHRF WWZ	Baofeng IAS of henan	*Rht-D1b*
Yumai 18	Zhengzhou 761/Yanshi 4	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 21	Bainong 791/Yumai 2//Lumai 1/Yanshi 4	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 25	Bainong 791//Wenxuan 1/Zhengzhou 761/3/Yumai 2	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 28	Line selected from Autumn-grown spring wheat Zhongzuo 8131-7	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 34	Aifeng 3//Meng 201/Neuzucht/3/Yumai 2	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 35	Mianyang 84-27/Neixiang 82C6//Yumai 17	YHRF WWZ	Henan AAS	
Yumai 47	Yumai 2/Baiquan 3199	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 49	Bainong 791//Wenxuan 1/Zhengzhou 761/3/Yumai 2	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 50	Taigu nuclear sterile agronomical population	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 51	Zhou 8425B/Yumai 17	YHRF WWZ	Henan AAS	
Yumai 54	Bainong 8717/3/Yanda 72-629-52/shi 82-5594//Bainong 84-4046-1	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 56	Zhengzhou 891/Zhou 8826//Ji 5418	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 57	Yumai 18/80(6)-3-3-10	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 62	Zhou 8425B/SWP73295	YHRF WWZ	Henan AAS	*Rht-D1b*

Table 1. *(continued)*

Yumai 63	C39/79(6) 9-2//Jimai 5418	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 69	Baiquan 3047-3/Neixiang 82C6	YHRF WWZ	Henan AAS	*Rht-D1b*
Yumai 70	Mianyang 84-27/Neixiang 82C6//Yumai 17	YHRF WWZ	Henan AAS	
Yun 97169	Unknown	YHRF WWZ	Shanxi AAS	*Rht-D1b*
Yunfengzao 101	Zheng 891/Yan 1604	YHRF WWZ	Shanxi AAS	
Yunfengzao 898	Unknown	YHRF WWZ	Shanxi AAS	
Yuzhan 9705	Fengyou 3(Yumai 47)/Laizhou 953	YHRF WWZ	Zhengzhou Exhibition Center	*Rht-D1b*
Zhengmai 9201	[Xiaoyan 6/xinong 65//83(2)3-3/84(14)43]F3/3/ Sha'an 213	YHRF WWZ	Zhengzhou IAS of Henan	*Rht-D1b*
Zhengmai 9405	Xi 881/8727//86(23)/Zhengzhou R84019	YHRF WWZ	Zhengzhou IAS of Henan	*Rht-D1b*
zhengyou 6	Zhengzhou 891/Zhou 8826//Ji 5418	YHRF WWZ	Zhengzhou IAS of Henan	
Zhengzhou 81-1	Baiquan 3199/8586-206	YHRF WWZ	Zhengzhou IAS of Henan	*Rht-D1b*
Zhengzhou 974	Neixiang 82C6/Zhengzhou 86115	YHRF WWZ	Zhengzhou IAS of Henan	
Zhengzhou 992	Ta Jian 79-1BC3/Zhou 9408//S-19/3/C831/Ta871349	YHRF WWZ	Zhengzhou IAS of Henan	*Rht-D1b*
Zhengzhou 7898	CM26/Wenmai 4(Yumai 41)	YHRF WWZ	Zhengzhou IAS of Henan	*Rht-D1b*
Zhengzhou 9023	[Xiaoyan 6/xinong 65//83(2) 3-3/84(14)43]F3/3/ Sha'an 213	YHRF WWZ	Zhengzhou IAS of Henan	*Rht-D1b*
Zhong 462	Xianyang 84 Plus 79/Yumai 21	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Zhong 892	786-11/(LK338/730-04)	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Zhongyu 5	Ji 5418/Yuxi 832	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Zhongyu 6	Zhongyu 3/Lumai 14	YHRF WWZ	Chinese Cotton Institute	
Zhongyu 415	Sha'anxi Fan 148－1/Shi 90－4185	YHRF WWZ	Chinese Cotton Institute	*Rht-D1b*
Zhou 91177	Zhoumai 9/Zhou 8425B	YHRF WWZ	Zhoukou IAS of Henan	*Rht-D1b*
Zhou 92031	Zhoumai 11/Zhoumai 9	YHRF WWZ	Zhoukou IAS of Henan	*Rht-D1b*
Zhoumai 11	Zhou 8425B/Yumai 17	YHRF WWZ	Zhoukou IAS of Henan	*Rht-D1b*
Zhoumai 13	Zhou 8425B/Zhoumai 9	YHRF WWZ	Zhoukou IAS of Henan	*Rht-D1b*
Zhoumai 16	Zhou 9/Zhou 8425B	YHRF WWZ	Zhoukou IAS of Henan	*Rht-D1b*
Zhoumai 17	Yumai 18/Zhou 8425B//Zhoumai 9	YHRF WWZ	Zhoukou IAS of Henan	*Rht-D1b*

Table 1. *(continued)*

Zhoumai 18	Zhoumai 11/Zhoumai 9	YHRF WWZ	Zhoukou IAS of Henan	*Rht-D1b*
Zimai 2	917065/910292	YHRF WWZ	Zibo IAS of Shandong	
99 P 077	Yangmai 92-90/Ningmaizi 23	Middle & Low Yangtze Valley WWZ (MLYV WWZ)	Lixiahe IAS of Jiangsu	
99 P 102	Ning 8026/Nannong 141	MLYV WWZ	Lixiahe IAS of Jiangsu	
Annong 91168	L13/(St2422/464)/Nainari 60//NPEP73	MLYV WWZ	Anhui AU	
Annong 94022	St2422/464//Nainari60//Zhu 14/St 1472/506	MLYV WWZ	Anhui AU	
Annong 98005	Aizao 781(Yuami 18)／Wanmai 19	MLYV WWZ	Anhui AU	*Rht-D1b*
E 66378	SKUA/865146//E'mai 11	MLYV WWZ	Hubei AAS	
E 81027	Ta1/8131-1	MLYV WWZ	Hubei AAS	
E 86642	8143/51143-2//chuan 35050	MLYV WWZ	Hubei AAS	*Rht-D1b*
E 91727	Ta1 Chang 151/En 1021//Jing 934	MLYV WWZ	Hubei AAS	
E'en 1	Lovrin 10/761//Sumai 3	MLYV WWZ	Enshi IAS of Hubei	*Rht-D1b*
E'mai 14	Fan 6/Yanda 72-629	MLYV WWZ	Hubei AAS	
Huaimai 16	Selected from Multi-parents	MLYV WWZ	Huaiyin IAS of Jiangsu	
Huaimai 17	Huaiyin 82057/Xuzhou 7471	MLYV WWZ	Huaiyin IAS of Jiangsu	
Huaimai 18	Zhengzhou 891/Lumai 14	MLYV WWZ	Huaiyin IAS of Jiangsu	*Rht-D1b*
Huaimai 894	C172/Gao 38 Bai //Qianfeng 1	MLYV WWZ	Huaiyin IAS of Jjiangsu	
Ning 9-159	Yangmai 6/West wind	MLYV WWZ	Jiangsu AAS	
Ning 97-18	MARINA/Yangmai 5//Yangmai 158	MLYV WWZ	Jiangsu AAS	
Ning 97-41	Ning 9170/Yangmai 158//Yangmai 158	MLYV WWZ	Jiangsu AAS	
Ning 9247	Yangmai 5/Yangmai 6	MLYV WWZ	Jiangsu AAS	
Ning 9415	SHA7/PRL"s"/VEE#6	MLYV WWZ	Jiangsu AAS	*Rht-D1b*
Ning 9548	DESC//VEE/PSN/3/YANG85-85	MLYV WWZ	Jiangsu AAS	*Rht-D1b*
Ning 9766	Yangmai 5/Yangmai 6//Yangmai 158	MLYV WWZ	Jiangsu AAS	
Ning 9940	Ningmai 8/Yangmai 158	MLYV WWZ	Jiangsu AAS	

Table 1. *(continued)*

Ning 9952	Ningmai 8/Yangmai 158	MLYV WWZ	Jiangsu AAS	
Ning 98084	Yangmai 158/SW893064	MLYV WWZ	Jiangsu AAS	*Rht-D1b*
Wanmai 18	Annong 8108/Bainong 3217	MLYV WWZ	Anhui AU	*Rht-D1b*
Wanmai 19	Bo'ai 74-22/Baofeng 7228(Yumai 2)	MLYV WWZ	Anhui AU	*Rht-D1b*
Wanmai 33	Annong 8326/Zhongzuo 8131-1	MLYV WWZ	Anhui AU	
Wanmai 38	Yanzhong 4/85-15-9	MLYV WWZ	Anhui AU	*Rht-D1b*
Yangmai 11	87-158/Y.G/Jian 2/85-84	MLYV WWZ	Lixiahe IAS of Jiangsu	
Yang 96-152	Unknown	MLYV WWZ	Lixiahe IAS of Jiangsu	*Rht-D1b*
Yang 97-65	Unknown	MLYV WWZ	Lixiahe IAS of Jiangsu	*Rht-D1b*
Yangfu 97-98	Yangmai 158/101-901	MLYV WWZ	Lixiahe IAS of Jiangsu	
Yangmai 5(soft)	Nanda 2419/Triumph//A'xuan 2/3/St1472/506	MLYV WWZ	Lixiahe IAS of Jiangsu	
Yangmai 9	Yangjian 3/Yangmai 5	MLYV WWZ	Lixiahe IAS of Jiangsu	
Yangmai 10	Yumai8⁎ Cc//Yangmai 5/3/4⁎ Yang 85-85/4/2⁎ Yangmai 158	MLYV WWZ	Lixiahe IAS of Jiangsu	
Yangmai 158	Yangmai 4/ST1472/506	MLYV WWZ	Lixiahe IAS of Jiangsu	
01-3570	96 Xia 440/Guinong 21	Southwestern WWZ (SWWZ)	Sichuan AAS	*Rht-D1b*
01-10251	73A/RI	SWWZ	Sichuan AAS	
01-DH 689	94-D.H-375/Mianyang 26	SWWZ	Sichuan AU	*Rht-D1b*
298-1	Miannong 4/45590	SWWZ	Chengdu Institute of Biology (CIB) of CAS	*Rht-D1b*
323-2	Zhongzhi 3586/50609	SWWZ	CIB of CAS	
992-17	9213-194/92B-4074	SWWZ	Dali IAS of Yunnan	*Rht-D1b*
3472	Anther cultrue from(Yanzhan A11/Yiyuan 2)F1γ-ray Treatment	SWWZ	Sichuan AAS	*Rht-D1b*
93 Xia 03-21	93-38-1/93-35	SWWZ	Sichuan AAS	*Rht-D1b*
98-1231	Chuanyu 12/87-429	SWWZ	Sichuan AU	*Rht-D1b*
98-1266	Chuanyu 12/87-429	SWWZ	Sichuan AU	
99-0502	911/MY86-51	SWWZ	Sichuan AAS	

Table 1. *(continued)*

9021	Compound crossing	SWWZ	Dali IAS of Yunnan	*Rht-D1b*
9962–6	9481/93N1001	SWWZ	Sichuan AAS	*Rht-D1b*
46648-1	(Chuanyu 5/Mo 460)//Mianyang 26	SWWZ	CIB of CAS	*Rht-D1b*
58512-2	Mianyang 90-309/92R171	SWWZ	CIB of CAS	
58749	SW3243/35050//21530	SWWZ	CIB of CAS	
58769-6	30220/8619-10	SWWZ	CIB of CAS	
99422	Mianyang 87-19/R1301	SWWZ	Sichuan AU	
An 96-8	L9288022-21/Xingnong 5	SWWZ	Anshun IAS of Guizhou	
Bi 2002-2	8513-1624/Ji 1002	SWWZ	Bijie IAS of Guizhou	
C2001-2	P92/P88	SWWZ	Sichuan AAS	
CD 1485-6	98718/Chuanyu 12	SWWZ	CIB of CAS	
Chuan 01018	R131/89-8//89-107	SWWZ	Sichuan AAS	*Rht-D1b*
Chuan 89-107	2469/80-28-7	SWWZ	Sichuan AAS	
Chuan 99-607	syn-CD769/SW3243//Chuan 6415	SWWZ	Sichuan AAS	
Chuan 99-1522	Syn-CD768/SW3243//Chuan 6415	SWWZ	Sichuan AAS	
Chuan 99-1572	Syn-CD768/SW3243//Chuan 6415	SWWZ	Sichuan AAS	
Chuan 96003	2469/80-28-7	SWWZ	Sichuan AAS	
Chuanmai 28	Wanya 2/77 Zhong 2874//Gaojiasuo/77 Zhong 2874/3/Mianyang 19	SWWZ	Sichuan AAS	*Rht-D1b*
Chuanyu 12	Chuanyu 8/83-4516	SWWZ	CIB of CAS	
Chuanyu 14	9920/21646	SWWZ	CIB of CAS	*Rht-D1b*
Demai 3	Longchun 2/Zhageping	SWWZ	Dehong IAS of Yunnan	
Demai 4	Bimai 5/ Ⅱ 8156(Mexico)//Zhongyin 1022	SWWZ	Dehong IAS of Yunnan	*Rht-D1b*
Fan 6	IB01828/NP824/3/5.1Mai//Chengdu Guangtou/Zhongnong 483/4/Zhongnong 28B/IB01828//NP824/Funo	SWWZ	Sichuan AU	*Rht-D1b*
Fengmai 24	Yunmai 36/Mo 965	SWWZ	Dali IAS of Yunnan	
Fengmai 27	7902/39491	SWWZ	Dali IAS of Yunnan	

Table 1. *(continued)*

Guizhou 9818	(Sumai 3/C39)/Qing 30	SWWZ	Guizhou AU	*Rht-D1b*
Jing 9308	TB78-212/Yin48/092-1	SWWZ	Qujing IAS of Yunnan	
Kefeng 14	8420//Neixiang 82C6F1/Yumai 17	SWWZ	Sichuan University	*Rht-D1b*
LB 0458	90-310/Mexico M180	SWWZ	*Southwest Sci. & Tech. University (SSTU)*	
Miannong 4	75-21-4/76-19//Miannong 1	SWWZ	Mianyang IAS of Sichuan	
Mianyang 11	70-5858/Fan 6	SWWZ	Mianyang IAS of Sichuan	
Mianyang 19	Selected from Mianyang 11(70-5858/Fan 6)	SWWZ	Mianyang IAS of Sichuan	
Mianyang 20	Selected from Mianyang 11(70-5858/Fan 6)	SWWZ	Mianyang IAS of Sichuan	
Mianyang 26	Chuanyu 9/Mianyang 20	SWWZ	Mianyang IAS of Sichuan	*Rht-D1b*
Mianyang 28	T79350-1-4-1-2/Mianyang 11	SWWZ	Mianyang IAS of Sichuan	*Rht-D1b*
Mianyang 29	Mianyang 11/Jiangyou 83-5	SWWZ	Mianyang IAS of Sichuan	
Mianyang 98-17	Mianyang 86-5/86-1114-2	SWWZ	Mianyang IAS of Sichuan	
Mianyang 98-20	Mianyang 20/92-8827	SWWZ	Mianyang IAS of Sichuan	*Rht-D1b*
Mianyang 99-3	053638-1/(Mianyang 87-24×81026-0-1-2)F4	SWWZ	Mianyang IAS of Sichuan	
Mianyang 351-15	Mianyang 99-310/Gansu M180	SWWZ	Mianyang IAS of Sichuan	
Mianyang 2000-8	Mianyang 86-78/Guinong 21 Xuan-1	SWWZ	Mianyang IAS of Sichuan	
Mianyang 2000-9	96EW37/Mianyang 90-100	SWWZ	Mianyang IAS of Sichuan	*Rht-D1b*
Mianyang 2000-13	Mianyang 01821/90 Zhong 165//Guinong 19-4	SWWZ	Mianyang IAS of Sichuan	
Mianyang 2000-18	Mianyang 96-5/Liaochun 10	SWWZ	Mianyang IAS of Sichuan	
Mianyang 2000-19	Mianyang 89-224/7705	SWWZ	Mianyang IAS of Sichuan	*Rht-D1b*
Mianyang 2000-34	(Mianyang 01821/903)/95-14426	SWWZ	Mianyang IAS of Sichuan	
Mianyang 940112	Mianyang 19/803	SWWZ	Mianyang IAS of Sichuan	
Mianyang 960107	1294/Mianyang 86-4	SWWZ	Mianyang IAS of Sichuan	

Table 1. *(continued)*

Mianyang 980127	1294/Mianyang 86-5	SWWZ	Mianyang IAS of Sichuan	*Rht-D1b*
N 711	92-4/Miannong 4	SWWZ	Sichuan AU	
N 1621-19-4	Mianyang 26/Yiyuan 2	SWWZ	Sichuan AU	
Nei 2938	Mianyang 26×92R178	SWWZ	Neijiang IAS of Sichuan	*Rht-D1b*
Nei 4103	Mianyang 26×92R178	SWWZ	Neijiang IAS of Sichuan	*Rht-D1b*
Nei 4221	Mianyang 26×92R178	SWWZ	Neijiang IAS of Sichuan	*Rht-D1b*
R 25	91S-23/A302	SWWZ	Sichuan AU	
R57	91S-23/A302	SWWZ	Sichuan AU	
R 59	91S-23/A302	SWWZ	Sichuan AU	
R 88	1104A/R935	SWWZ	Sichuan AU	
R 97	Mianyang 92-8/91S-5-7	SWWZ	Sichuan AU	
R 111	961-225/91S-5-4	SWWZ	Sichuan AU	
R 122	(96Ⅰ-22/133-3)/Mianyang 26	SWWZ	Sichuan AU	
R 131	915-23/Qianhui 3	SWWZ	Sichuan AU	
SW 8588	Milan's'/SW5193	SWWZ	Sichuan AAS	
W 7	Yingli Wheat/Xianyangdasui//W7268	SWWZ	CIB of CAS	
Xike 0106-1	Chuanyu 11/9310-6	SWWZ	SSTU	
Xike 01015	Mianyang 26/Zhi 39060-4	SWWZ	SSTU	
Y 1496-15	94-2/Miannong 4	SWWZ	Sichuan AU	*Rht-D1b*
Yi 99-49	Chuanyu 12/85-5	SWWZ	Yibing IAS of Sichuan	*Rht-D1b*
Yi 99-81	90036-5-1/89-311	SWWZ	Yibing IAS of Sichuan	
Yin 11-20	NG8319//SHA4/LIRA	SWWZ	Yunnan AAS	
Yu 94-7	Chuanya 84-2/91-125	SWWZ	Chongqing AAS	*Rht-D1b*
Yumai 3	81-2/8334	SWWZ	Yuxi IAS of Yunnan	
Yunmai 39	Yunmai 29/Flicker“S”	SWWZ	Yunnan AAS	
Yunmai 42	Kangxiu 782/Yunmai 29//YR70-RAM“S”	SWWZ	Yunnan AAS	

Table 1. *(continued)*

Yunmai 44	Xingmai 1/VEERYS//LBPRING-173	SWWZ	Yunnan AAS	
Yunmai 46	Veery "s"/82B-477//83D4-1	SWWZ	Yunnan AAS	
Ke 92 R-172	Kehan 12/Ke 82-371	Northeastern SWZ	Heilongjiang AAS	
Kefeng 6	Ke 85F3-868/Ke 85F6-784	Northeastern SWZ	Heilongjiang AAS	
Kehan 16	Jiusan 79F55416/Ke 80 Yuan 229//Ke 76-750/Ke 76F4779-5/3/Ke 76-413	Northeastern SWZ	Heilongjiang AAS	
Liaochun 10	Ke 71F4-370-10/Mexipak 66//UP321/3/Liao 6/Jinghong 1	Northeastern SWZ	Liaoning AAS	
Liao 97 Jian 30	Unknown	Northeastern SWZ	Liaoning AAS	*Rht-D1b*
Liao 98 Jian 419	Unknown	Northeastern SWZ	Liaoning AAS	
Long 96-6239	Ke 88-779/Longfumai 3	Northeastern SWZ	Heilongjiang AAS	
Long 97-7146	Long 90-05092/Long 90-06351	Northeastern SWZ	Heilongjiang AAS	
Long 98-8019	Long 88-814/Kefeng 2//Kefeng 8/Long 84-4699	Northeastern SWZ	Heilongjiang AAS	
Longmai 19	Long 74-5778/Ke 74-202	Northeastern SWZ	Heilongjiang AAS	
Longmai 26	Long 87-7129/Ke 88F5-2060	Northeastern SWZ	Heilongjiang AAS	
Shenmian 90	Unknown	Northeastern SWZ	Shenyang AU	
Shenmian 99042	Unknown	Northeastern SWZ	Shenyang AU	
Shenmian 99121	Unknown	Northeastern SWZ	Shenyang AU	*Rht-D1b*
Xinkehan 9	Kefeng 2/Ke 74F3-249-3	Northeastern SWZ	Heilongjiang AAS	
Ba 97-5797	Chuannong 91—2848/Bamai 6	Northern SWZ	Bameng IAS of Neimenggu	
Ba 97-5965	D79/Bafeng 1	Northern SWZ	Bameng IAS of Neimenggu	*Rht-D1b*
Ba 97-8397	Ke B1/Yongliang 12	Northern SWZ	Bameng IAS of Neimenggu	*Rht-D1b*
Ba 97-8812	LZ541/Yufeng 1	Northern SWZ	Bameng IAS of Neimenggu	
Ba 97-9040	Ba 1407/Ji 84—5418//Yongliang 4	Northern SWZ	Bameng IAS of Neimenggu	
Ba 98-7997	Bamai 6/Yong 492	Northern SWZ	Bameng IAS of Neimenggu	*Rht-D1b*
Ba 98-8405	Ningnong 178//Tiechun 2/Q16	Northern SWZ	Bameng IAS of Neimenggu	*Rht-D1b*
Bayou 1	Ji 84-5418/Ningchun 4	Northern SWZ	Bameng IAS of Neimenggu	
Jinchun 14	Tal Aibai /Y465/Jinchun 9(Tal/163-12)	Northern SWZ	Shanxi AAS	*Rht-D1b*

Table 1. *(continued)*

Jizhangchun 5	Chabei 102/Jinghong 2	Northern SWZ	Hebei Baxia IAS	*Rht-D1b*
Neimai 19	81NS10 Winter Taigu neuclear nonsterile/Ningchun 4	Northern SWZ	Neimenggu AAS	*Rht-D1b*
95-111-6-3	92R137//Lantian (Bluesky) 1/83-809	Northwestern SWZ	Tishui AU of Gansu	
CM 4860	CMBW90M4860-0TOPY-16M-1Y-010M-010Y-01M-0	Northwestern SWZ	Gansu AAS	
Gaoyuan 602	Gaoyuan 182//Kechun 5/Yan 759	Northwestern SWZ	Qinhai AAS	
Lantian(Blue sky) 9	Xifeng 16/76-89-13	Northwestern SWZ	Lanzhou AU of Gansu	
Longchun 15	75002/Shanqianmai	Northwestern SWZ	Gansu AAS	
Ningchun 4	Sonora 64//Abbondanza/Quality	Northwestern SWZ	Ningxia AAS	*Rht-D1b*
Qinchun 533	Jubilena Ⅱ/c285//Xingfumai/3/Rondine/4/Tanworth8704-84/5/Alondra"S"-76	Northwestern SWZ	Qinhai AAS	
Qinchun 566	Jubilena Ⅱ/c285//Abbondanza 10Kr/Saric/3/Abbondanza 108 Autumn3-5-1-2/Yecora	Northwestern SWZ	Qinhai AAS	
Chunguanpu 64-1	Jimai 30/Xinchun 2	Xinjiang WSZ	Xinjiang AAS	
Xinchun 2	Co-Y-ray radiating seeds of Xite.Sailuosi/Qichun 4	Xinjiang WSZ	Xinjiang AAS	*Rht-D1b*
Xinchun 6	Zhong 7906/Xinchun 2	Xinjiang WSZ	Xinjiang AAS	
Xinchun 9	NS265 From Canada	Xinjiang WSZ	Xinjiang AAS	
Xindong 18	NS11-33/Xindong 3	Xinjiang WSZ	Xinjiang AAS	
Xindong 22	Nostra/Huachun 84-1//76-4/Lovrin 13	Xinjiang WSZ	Xinjiang AAS	*Rht-D1b*
Xindong 24	9245/Jimai 9159	Xinjiang WSZ	Xinjiang AAS	
Xindong 25	Jimai 885-443/Jimai 88-5282	Xinjiang WSZ	Xinjiang AAS	

Table note: A total of 421 genotypes mainly from 8 of 10 wheat zones in China, which have been widely and commercially grown during the last decade and about half of them still being grown now, have been detected by STS electrophoresis of PCR product amplified with the STS Marker developed by Ellis (2002) specific for the *Rht-D1b* gene. Pedigree information of the selected cultivars and lines was kindly provided by various breeders and some from Zhuang (2003) and Jin (1996). The results of all wheat cultivars and lines tested along with their pedigree, breeding place, wheat zone and genotype, are listed as blow in Table 1. In the Table, AAS was abbreviated for academy of agricultural sciences, IAS for institute of agricultural sciences, AU for agricultural university, WWZ for winter wheat zone, SWZ for spring wheat zone and WSZ for winter-spring zone.

Wheat Inf. Serv. 102: 26-28, 2006. www.shigen.nig.ac.jp/ewis

Research Information

Wheat lines showing high flooding tolerance at reproductive growth stage

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Abstract
To identify flooding-tolerant wheat lines at reproductive growth stage, ten lines selected by the previous seedling test were grown under flooding condition from seedling to maturing growth stage, and their flooding tolerance was assessed. Among ten wheat lines, U-1339, CNT-1 and #660 exhibited high tolerance with almost normal growth and fertility. These three lines were useful genotypes for developing highly flooding-tolerant as well as waterlogging-tolerant wheat lines.

Wheat (*Triticum aestivum* L.) is one of the most intolerant crops to soil waterlogging (Thomson et al. 1992). Soil waterlogging is a serious problem especially in central and southern parts of Japan, where wheat plants are cultivated in upland fields converted from rice paddy fields. Varietal difference of waterlogging tolerance was reported among wheat lines (Musgrave 1994), indicating that waterlogging tolerance is genetically controlled trait. From 1986 to 1988 in Japan, the genetic variation of waterlogging tolerance in wheat at seedling stage was examined by large-scale screening in National Agricultural Research Center for Western Region. Among more than 2,000 wheat lines, ten were selected as highly waterlogging-tolerant lines at the seedling stage (unpublished data; personal communication by N. Ishikawa). In this study, to identify highly waterlogging-tolerant lines at reproductive growth stage, ten lines selected by the previous seedling test were grown under flooding condition from seedling to maturing growth stage, and their flooding tolerance was assessed.

Ten wheat lines used in this study are as follows. U-1339 from Nepal, CNT-1 from Paraguay, Tohoku 185 from Japan, and #660 from Italy, which were selected as waterlogging-tolerant lines by the seedling test of 1986. NOVOSADSKA CREVENA, ISKRA and NS-302, all from Yugoslavia, were screened in the seedling test of 1987. Norin 12, Fukuhokomugi and Koyukikomugi, all from Japan, were screened in the seedling test of 1988. In addition to these ten lines, Chinese Spring, a standard line for wheat research, was used in the experiment. Seeds were sprouted in a growth chamber at 23℃, and seedlings were transplanted into soil in 1/5000a Wagner’s pot with a drain hole in a green house at 25℃. One pot was used for one seedling. Soil containing fertilizer for growing rice (Kumiai Lovely Tokotsuchi; N 0.36g, P 0.36g, K 0.36g /kg) was provided from JA Fukui Prefectural Economic Federation of Agricultural Cooperatives, and used in this experiment. For a dry-field condition pot (plot D), a wheat plant was grown in a soil-filled pot with the drain hole open. For a flooding condition pot (plot F), a seedling at the 1-leaf stage was flooded at about 2cm above the soil surface in a soil-filled pot with the drain hole plugged, and the plant was grown until harvest time under the flooding condition. The following six characters were examined in maturing stage; culm length, tiller number per plant, ear length, spikelet number per ear, grain number per ear, and 1000-grain weight. Culm length, ear length, spikelet number per ear and grain number per ear were measured using the main shoot and its ear of each plant. These characters and tiller number were observed in two to five plants per line in each plot D and F, and the averages were subjected to statistical analysis. The 1000-grain weight was measured for grains from two to five ears per line. The effects of flooding on plant growth were assessed in comparison with plot F with plot D (F/D value: ratio of plot F to plot D).

Table 1 shows the mean values of six agronomic characters in ten wheat lines with high waterlogging-

Table 1. Evaluation of flooding tolerance in eleven wheat lines

Line	Plot	Culm length (cm)	Tiller no. /plant	Ear length (cm)	Spikelet no./ear	Grain no. /spikelet	1000-grain wt (g)	Flooding tolerance (Class)
U-1339	D[1)]	49.8	4.3	9.5	14.0	2.13	44.4	High
	F[2)]	60.0	7.5	9.5	14.5	1.55	29.3	
	F/D[3)]	1.20ns	1.74*	1.00ns	1.04ns	0.73*	0.66	(IV)
CNT-1	D	85.0	4.5	7.7	15.3	1.36	28.4	High
	F	76.3	5.7	7.7	18.0	1.22	18.2	
	F/D	0.90ns	1.27ns	1.00ns	1.18ns	0.90ns	0.64	(IV)
Tohoku 185	D	54.5	3.8	7.0	21.5	0.60	33.1	Low
	F	-	-	-	-	-	-	
	F/D	-	-	-	-	-	-	(I)
#660	D	85.5	4.3	8.8	18.5	0.98	23.9	High
	F	78.0	6.3	10.5	22.0	0.67	31.2	
	F/D	0.91*	1.47ns	1.19*	1.19*	0.68ns	1.31	(IV)
NOVOSADSKA	D	65.7	3.3	6.0	19.7	1.25	19.2	Intermediate
CREVENA	F	40.0	3.0	5.2	16.0	0	-	/sterile
	F/D	0.61ns	0.91ns	0.87ns	0.81ns	0	-	(II)
ISKRA	D	58.3	4.3	6.2	17.0	1.28	24.7	Low
	F	-	-	-	-	-	-	
	F/D	-	-	-	-	-	-	(I)
NS-302	D	53.5	5.5	5.9	21.3	0.97	23.4	Intermediate
	F	36.5	5.0	5.8	18.0	0	-	/sterile
	F/D	0.68ns	0.91ns	0.98ns	0.85ns	0	-	(II)
Norin 12	D	43.4	4.2	4.5	15.8	0.78	27.4	Low
	F	-	-	-	-	-	-	
	F/D	-	-	-	-	-	-	(I)
Fukuhokomugi	D	56.3	4.0	8.2	20.3	2.23	25.5	Intermediate
	F	30.0	3.5	8.1	17.0	1.77	6.7	/fertile
	F/D	0.53*	0.88ns	0.99ns	0.84**	0.79ns	0.26	(III)
Koyukikomugi	D	49.8	4.0	5.7	18.0	0.96	30.4	Intermediate
	F	33.0	2.0	5.1	21.0	0.54	15.7	/fertile
	F/D	0.66**	0.50*	0.89ns	1.17*	0.56ns	0.52	(III)
Chinese Spring	D	68.5	8.5	8.8	23.0	1.89	21.2	Intermediate
	F	46.5	5.0	7.1	18.5	1.35	5.7	/fertile
	F/D	0.68*	0.59ns	0.81*	0.80*	0.71**	0.27	(III)

1) Plot D: dry-field condition plot
2) Plot F: flooding condition plot
3) F/D value: ratio of plot F compared to plot D. ns means no significance between plot D and F by t-test., * and ** indicate significantly different at 5 and 1% levels, respectively.

tolerance at seedling stage and wheat cv. Chinese Spring grown, under plots D and F. Eleven lines were divided into four classes of flooding tolerance. Tohoku 185, ISKRA and Norin 12 were highly susceptible to flooding, and died during the vegetative growth stage in plot F (class I). NOVOSADSKA CREVENA and NS-302 showed no significant difference in culm length, tiller number, ear length and spikelet number per ear, but were completely sterile (class II). Fukuhokomugi, Koyukikomugi and Chinese Spring showed seed fertility but decreased 1000-grain weight (less than 0.6 in F/D value) (class III). This was due to shriveled kernels found in the plants of plot F (Fig. 1). U-1339, CNT-1 and #660 exhibited high flooding tolerance, with almost normal growth and there are no shriveled kernels in plot F (Fig. 1) (class IV).

This study revealed that ten wheat lines selected as high waterlogging-tolerant lines at seedling stage exhibited different flooding tolerance when they were grown under flooding condition from seedling to maturing growth stage. Wheat lines of class I was highly susceptible to flooding and died during the vegetative growth stage. Class II is intermediate

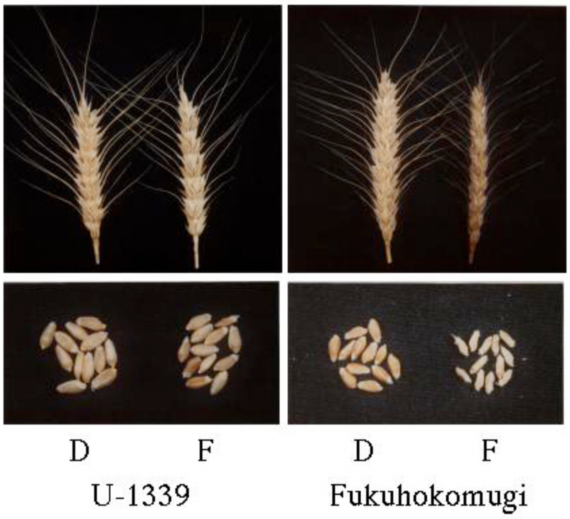

Figure 1. Ears and grains of U-1339 with high and Fukuhokomugi with intermediate flooding tolerance grown under a dry-field condition (D) and a flooding condition (F).

type showing almost normal growth but completely sterility. Class III is also intermediate type showing almost normal growth and fertility, but yielding shriveled kernels. In soybean, Scott et al. (1989) reported that the early reproductive stage is more sensitive to flooding than vegetative stage. The present data suggest that in also wheat reproductive organs were more seriously damaged than vegetative organs by flooding. Based on a field test, Musgrave (1994) reported that yield depression of wheat plants caused by water stress was due to reduced grain number and grain weight. These findings indicate that we have to identify flooding-tolerant lines by the reproductive stage test as well as the seedling test for practical breeding program. Three lines of class IV have high flooding tolerance and show normal growth and fertility. These three cultivars, U-1339, CNT-1 and #660, came from different countries, i.e., Nepal, Paraguay and Italy, respectively, suggesting that different genes may be involved in the flooding adaptability. It is possible that we can develop wheat lines with higher flooding tolerance by pyramiding of these genes. Furthermore, these lines could be useful to study the mechanism of flooding tolerance in wheat.

Acknowledgements

Thanks are due to Dr. N. Ishikawa, National Agricultural Research Center for Western Region for providing wheat materials. Thanks are also due to Dr. A. Oyanagi, National Agricultural Research Center for Tohoku Region for valuable suggestions. This work was supported in part by a Grant-in-Aid for Exploratory Research from the Ministry of Education, Science and Culture of Japan (No. 23401).

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