SABRAO Journal
of Breeding and Genetics
36(1) 39-43, 2004

YIELDING PERFORMANCE OF A JAPONICA RICE F_1 HYBRID CARRYING *Undulate rachis -1* (*Ur1*) GENE UNDER A HIGH-HILL DENSITY CONDITION

MASAYUKI MURAI[1]*, ATSUSHI NAGAYAMA[1], SHIGETOSHI SATO[2], HARI BAHADUR KC[1,3] , KAZUO ISE[4], and KAZUSHIGE NISHII[1]

SUMMARY

An incompletely dominant gene *Undulate rachis -1* (*Ur1*) increases secondary branching resulting in more spikelets per panicle, which brings about a greater sink size. Two F_1s with *Ur1*/ + and +/+ genotypes (H^U and H^+) were produced by crossing 'Nishihikari' (common maternal parent, short-culm variety) with the two isogenic lines of 'Taichung 65' carrying both *Ur1* and *sd1*, and *sd1* only, respectively. H^U, H^+, and the check inbred variety 'Hinohikari' were grown at two hill densities (22.2 and 44.4 hills per m^2). The yield of H^+ was 7% (42 g/m^2) higher than that of 'Hinohikari' at the high hill density. Moreover, H^U had a 12% (75 g/m^2) higher yield than H^+. Neither F_1 showed a significant hill-density response for yield. H^U had 21% more spikelets per panicle than H^+ at the high-hill density. Each F_1 showed a negative response in spikelet number per panicle from medium- to high-hill densities, while H^U was more responsive than H^+. There was no significant difference in panicle number per m^2 between the two F_1s. Regarding ripened-grain percentage and 1000-grain weight, H^U was lower than H^+. Thus, yield of H^U did not significantly increase from medium- to high-hill densities, because its spikelet number per panicle decreased.

Key words: *Oryza sativa, Ur1*, heterosis, hybrid rice, spikelet number per panicle, yield, sink size, hill density

Undulate rachis -1 (*Ur1*) is an incompletely dominant gene on chromosome 6 (Nagao et al., 1958; Sato and Shinjyo, 1991). *Ur1* increases not only the number of secondary branches per panicle but also the spikelet number per secondary branches, resulting in a larger spikelet number per panicle (Murai and Iizawa, 1994). This genic effect increased grain yield at both *Ur1/Ur1* and *Ur1*/.+ genotypes by enlarging sink size under the genetic background of a japonica variety, 'Taichung 65', despite the reduction in ripened-grain percentage (Murai et al., 1997 and 2002).

Murai et al. (1997 and 2003) produced two F_1s with *Ur1*/ + and +/+ genotypes (H^U and H^+) by crossing 'Nishihikari' (common maternal parent) with the two isogenic lines of 'Taichung 65' carrying both *Ur1* and *sd1*, and *sd1* only, respectively, and reported that H^U had 7 to 11% higher brown rice yields than H^+ at various fertilizer levels. Thus, the yield-increasing effect of *Ur1* was superimposed upon the high yield ability of H^+, suggesting that *Ur1* is a useful tool for developing high-yielding F_1 varieties.

[1] Faculty of Agriculture, Kochi University, Monobe, Nankoku, Kochi 783-8502, Japan;
[2] College of Agriculture, University of Ryukyus, Senbaru, Nishihara, Okinawa 903-0129, Japan;
[3] Nepal Agricultural Research Council, Khumaltar, G.P.O. Box 1135, Kathmandu, Nepal; and
[4] Japan International Research Center for Agricultural Sciences, Tsukuba, Ibaraki 305-8686, Japan.
* Corresponding author: muraim@cc.kochi-u.ac.jp.

In the present study, H^U, H^+, and 'Hinohikari'- a leading variety in Southern Japan were grown with high- and medium-hill densities in a rather high fertilizer level. Its yield and related traits were also measured. Thus, whether H^U can gain a higher yield by growing under the high-hill density condition was examined.

MATERIALS AND METHODS

'Nishihikari', the common maternal parent for H^U and H^+, is a short culm- and panicle-number type variety possessing the highest lodging tolerance in Southern Japan (Nishiyama, 1982). The *Ur1-sd1* isogenic line of 'Taichung 65' and the *sd1* isogenic line of 'Taichung 65' were used as paternal parents for H^U and H^+, respectively (Murai et al., 2003). Crossed seeds for the two F_1s were obtained by the emasculation with a pincette. 'Hinohikari', the representative inbred variety of Southern Japan, was used as the check variety for the two F_1s. This inbred variety has long culm, many panicles, and medium maturity (Yagi, 1989; Murai et al., 2003).

On May 26,1999, the 24-day-old seedlings of H^U, H^+, and 'Hinohikari' were transplanted to a paddy field of the Faculty of Agriculture, Kochi University, Japan, with two seedlings per hill at medium and high hill densities, viz. 22.2 hills per m^2 (30 x 15 cm) and 44.4 hills per m^2 (30 x 7.5 cm), respectively. The former hill density is popular in the rice cultivation of Japan. The split-plot design was adapted to the experimental field, applying the main- and sub-plots to hill density and genotype, respectively, with three replications. The medium-hill density plots for the three entries in the study were quite the same as those at the high fertilizer level in Murai et al. (2003). At both hill densities, 12 g/m^2 for each of N, P_2O_5, and K_2O was applied by both the basal dressing (60%) and the top dressing at the panicle formation stage (40%). H^U, H^+, and 'Hinohikari' had 80% heading dates on August 14, 12 and 14, respectively, at the high-hill density condition.

Plot size, way of sampling, measurements of yield and other traits in the study were the same as those in Murai et al. (2003). Hulled ripened-grain weight (yield) was measured after sieving at 1.7 mm, and yield was estimated at 15% moisture content.

RESULTS

The standard heterosis of H^+ to 'Hinohikari' was evaluated before examining the yielding performance of H^U (Table 1). The yield of H^+ was 7% (42 g/m^2) higher than that of 'Hinohikari' at the high-hill density condition, which was principally due to its higher 1000-grain weight than that of 'Hinohikari'. H^+ had a higher ripened-grain percentage but fewer panicles per m^2 than 'Hinohikari', although neither difference was significant. In spikelet number per panicle as well as panicle length, H^+ was similar to 'Hinohikari'. H^+ had a shorter culm length than 'Hinohikari'.

The analysis of variance for the two F_1s at the two hill densities was conducted for each trait, to examine the heterozygous effect of *Ur1*, hill-density effect, and the interactive effect under the genetic background of H^+ (Table 2). H^U had a 12% (75 g/m^2) higher yield than H^+ at the high-hill density condition (Table 1). This yield corresponded to 121% that of 'Hinohikari'. The hill-density effect was not significant, although H^U showed a little yield increase (5 g/m^2) from the medium to high hill densities.

H^U had 21% larger spikelet number per panicle than H^+ at the high-hill density condition. The hill density effect and the hill density x *Ur1* interaction were both significant. Each F_1 had a smaller value of this trait at the high-hill density than at the medium-hill density condition, and H^U was more responsive than H^+ (decreases by 13.5 and 7.6, respectively).

There was no significant difference in panicle number per m^2 between the two F_1s. In this trait, both F_1s showed increases from the medium to high-hill densities, although the hill-density effect was not significant.

Regarding ripened-grain percentage as well as 1000-grain weight, H^U was significantly lower than H^+. In both traits, value of H^U increased from the medium- to high-hill densities although the hill-density effect was not significant. On the other hand, H^+ showed little hill-density response.

H^U was 20% and 16% larger than H^+ in spikelet number per m^2 and sink size, respectively. The hill-density effect was significant for spikelet number per m^2. The value of this trait in H^U decreased from the medium- to high-hill densities whereas H^+ showed little hill-density response. The hill-density responses of the two F_1s in sink size were similar to those in spikelet number per m^2.

Regarding the total weight at maturity, the effect of *Ur1* was significant, and H^U was larger than H^+. Moreover, H^U was higher than H^+ in harvest index. The hill-density effect was not significant in either trait.

H^U was 12.0 and 1.8 cm longer than H^+ in culm and panicle lengths, respectively. Both F_1s showed negative-hill density responses in both traits.

Table 1. Yield and other traits of H^U and H^+ at high hill density, and their responses from medium to high hill densities expressed by + or - values.

Trait	H^U	H^+	$LSD_{(5\%)}$ [1]
Yield (g/m^2)	687** (112) [2] +5 [4]	612 [107*] [3] +1 [4]	36
Spikelets / panicle	94.0**(121) -13.5	77.8 [100] -7.6	4.1
Panicles / m^2	345 (99) +19	348 [96] +24	15
Ripened-grain percentage	90.1* (97) +5.1	93.0 [104] +1.2	2.9
1000 grain weight (g)	23.5** (97) +0.7	24.3 [108**]+0.2	0.8
Spikelets / m^2 (x 100)	325** (120) -26	270 [96] -7	24
Sink size [5] (g/m^2)	763** (116) -38	657 [103] -9	58
Total weight at maturity [6] (g/m^2)	1542 (104) -28	1479 [— [8]] +24	113
Harvest index [6] (%)	37.9* (108) +1.0	35.2 [— [8]] -0.5	2.3
Culm length [7] (cm)	84.4** (116) -5.4	72.4 [92**] -4.2	2.0
Panicle length [7] (cm)	20.1** (110) -0.5	18.3 [102] -0.7	0.7

[1] Calculated from sub-plot errors of the analysis of variance (Table 2); [2] H^U / H^+ (%); [3] H^+ / 'Hinohikari' (%); [4] Hill density response: high hill density - medium hill density; [5] Single grain weight x spikelets / m^2; [6] Dry matter basis; [7] Measured for the longest culm of each hill at maturity; [8] No measurement for 'Hinohikari'.
*,**Difference between H^U and H^+ or between H^+ and 'Hinohikari' was significant at the 5 and 1% levels, respectively.

DISCUSSION

The yield of H^U did not significantly increase from the medium- to high-hill densities, because its spikelet number per panicle decreased. The larger spikelet number per panicle in H^U (Table 1) was due to the characteristic panicle type with more secondary branches per panicle, resulting from the effect of *Ur1* (Murai and Iizawa, 1994). Murai et al. (1981) reported that a cool temperature treatment at the booting stage induced spikelet degeneration at the upper part of the panicles for a *Ur1*-carrying line. It is inferred that the unusually narrow intra-row distance intensified the competition between hills accelerating the degeneration of secondary branches as well as secondary-branch spikelets. According to Murai et al. (2003), H^U was more responsive to fertilizer level than H^+ in spikelet number per panicle; moreover, H^U attained a high yield (723 g/m^2) with heavy fertilizer application (N=16 g/m^2 in total) at medium-hill density. Consequently, the medium-hill density with a high fertilizer level may be adequate to pursue high yield using an F_1 hybrid carrying *Ur1*.

Table 2. Analysis of variance for the split-plot experiment applying the hill densities and the two F_1s (H^U and H^+) to main-plot and sub-plot, respectively, in yield and other traits.

Trait	Source of variation [1]		
	Hill density	*Ur1* [2]	Interaction (H. d. x *Ur1*)
Yield (g/m^2)	<1 [3]	68.28** [3]	<1 [3]
Spikelets / panicle	79.54*	334.25**	7.90*
Panicles / m^2	7.81	<1	1.37
Ripened-grain percentage	10.79	39.81**	5.92
1000 grain weight (g)	3.38	22.65**	<1
Spikelets / m^2 (x 100)	23.50*	116.32**	4.32
Sink size [4] (g/m^2)	13.08	69.57**	2.13
Total weight at maturity (g/m^2)	<1	10.20*	2.12
Harvest index (%)	<1	11.70*	1.83
Culm length (cm)	282.71**	635.07**	1.66
Panicle length (cm)	21.29*	81.17**	<1

[1] Degrees of freedom for hill density (main-plot), *Ur1* (sub-plot), the interaction, block, main-plot error and sub-plot error are 1, 1, 1, 2, 2 and 4, respectively. [2] Difference between H^U and H^+. [3] Numerals in the table indicate F-values. [4] Single grain weight x spikelets / m^2.
*,**Significant at the 5 and 1% levels, respectively.

ACKNOWLEDGEMENTS

We are indebted to Mr. Y. Takemura and Mr. M. Urabe, Kochi University for their cooperation in carrying out the experiment.

REFERENCES

Murai, M., T. Kinoshita, and M. Takahashi. 1981. Influences of cold water for the character expression of the six kinds of major genes responsible panicle type. Genetical studies on rice plant, LXXIX. *Res. Bull. Univ. Farm Hokkaido Univ.* 22: 46-55.

Murai, M., and M. Iizawa. 1994. Effects of major genes controlling morphology of panicle in rice. *Breed. Sci.* 44: 247-255.

Murai, M., K. Ise, S. Sato, and I. Takamure. 1997. Utility of *Ur-1* for developing F_1 cultivars. In: L. Yuan, ed, *Proc. of the International Symposium on Two-line System Heterosis Breeding in Crops.* China National Hybrid Rice Research and Development Center, Changsha, China. pp. 146-151.

Murai, M., Y. Sato, A. Nagayama, N. Ishii, and S. Ihashi. 2002. Effects of a major gene *Ur1* characterized by undulation of rachis branches on yield and its related traits in rice. *Breed. Sci.* 52: 299-307.

Murai, M., A. Nagayama, S. Sato, H. B. Kc, K. Ise, and T. Yoshida. 2003. High yielding F_1 hybrid carrying *Ur1* (Undulate rachis-1) gene in *japonica* rice. *Breed. Sci.* 53: 263-269.

Nagao, S., M. Takahashi, and T. Kinoshita. 1958. Genetical studies on rice plant, XXIII. Inheritance on a certain ear type in rice. *Mem. Fac. Agr. Hokkaido Univ.* 3: 38-47.

Nishiyama, H. 1982. A new rice variety 'Nishihikari'. *J. Agric. Sci.* (Nogyou gijutu) 37: 125-127. (In Japanese)

Sato, S., and C. Shinjyo. 1991. Genetic studies on genetic male sterile mutant obtained through breeding of isogenic translocation line of 'Taichung 65' in rice, *Oryza sativa* L. *Japan. J. Breed.* 41: 451-459.

Yagi, T. 1989. A new rice variety 'Higonohana' and 'Hinohikari'. *J. Agric. Sci.* (Nogyou gijutu) 44: 420-421. (In Japanese)