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IDENTIFICATION AND UTILISATION OF WIDE COMPATIBILITY GENE IN RICE

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ABSTRACT

A set of *indica* and tropical *japonica* genotypes were screened for wide compatibility by crossing them with suitable *japonica* and *indica* testers. The genotypes showed variation for wide compatibility. Dular and 9314 were found to be the ideal *indica* and tropical *japonica* 'WC' lines respectively. Pusa 743 and 9313 failed to qualify as wide compatible varieties. Wide compatible varieties when used as male parents exhibited positive effects in their hybrids in respect of some traits like number of spikelets and spikelet fertility. On account of many advantages, it is found desirable to develop tropical *japonica* CMS lines and TGMS lines. To exploit the positive effects of WC parents from male side, possibilities of developing both parents with 'WC' gene are suggested to develop heterotic *indica* /tropical *japonica* hybrids.

Key words : Rice, wide compatibility, Heterosis, Inter sub-specific hybrids

The magnitude of heterosis for yield and other agronomic traits depends to a large extent on genetic differences between parents [1]. It is reported [2, 3] that highest level of heterosis is observed in *indica/japonica* crosses followed by *indica/indica and japonica/japonica* crosses in that order. Development of *indica /japonica* inter sub-specific hybrids, therefore, assumes greater significance in realising higher magnitude of heterosis, which is a prerequisite for widespread adoption of hybrid rice technology. The *indica/japonica* hybrids were thought to be impossible until the discovery of 'wide compatibility (WC) gene [4] which overcomes the problem of F_1 hybrid sterility in such hybrids. It is widely confirmed that the semi-sterility observed in most of the *indica/japonica* hybrids is due to gamete abortion caused by an allelic interaction at a locus on chromosome 6 [3, 5]. *Indica* and *japonica* lines have $S\text{-}5^i$ and $S\text{-}5^j$ alleles respectively, while some *javanica* (tropical *japonica*) lines have been reported to possess a neutral allele $S\text{-}5^n$ also called the 'WC' gene. The $S\text{-}5^i/S\text{-}5^i$

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genotypes show gamete abortion, but S- 5^i/S-5^n or S-5^j/S-5^n do not. This 'WC' gene has been incorporated into *japonica* types and successfully used for obtaining *indica/japonica* hybrids [6, 7] with higher level of heterosis. Therefore, identification of 'WC' gene sources becomes important either for its direct utilisation in the development of inter sub-specific hybrids or for further use in breeding of parental lines with 'WC' gene. In this paper we discuss the identification of useful sources of 'WC' gene and its utilisation in breeding for *indica/japonica* inter sub-specific hybrids.

MATERIALS AND METHODS

During wet season 1995 and dry season 1995-96, about 40 hand crosses were made between selected *indica* and *japonica* (both tropical and temperate) genotypes with suitable testers. IR 36, IR 50, Nagpur 27 were the *indica* testers, while Akihikari, J3, J7, J8 and J72 were used as *japonica* testers for screening wide compatible (WC) genotypes. During wet season 1996, the F_1 crosses were evaluated in field. Each F_1 cross was grown in a single row of 3 m length bordered by a check variety Ajaya on either side. The spacing was 20 cm between rows and 15 cm between plants. Standard agronomic practices were adopted. The data were recorded on 5 plants for plant height (HT), panicle number (PN), panicle length (PL), number of filled spikelets (FS), spikelet fertility per cent (SFP), 100 grain weight (TW) and grain yield/plant (SYP). The data were used for identifying the sources of 'WC' gene and its influence on the expression of some agronomic traits in hybrids.

RESULTS AND DISCUSSION

IDENTIFICATION OF 'WC' GENE

Table 1, presents the spikelet fertility per cent in F_1 crosses between *indica*, *japonica* and wide compatible varieties (WCVs). It is clear from the table that most crosses involving *indica* and *japonica* (testers) showed normal fertility except those involving Pusa 743. There were clear differences in fertility level attributable to individual 'WC' genotypes. For instance, out of the two *indica* 'WC' sources, viz., N22 and Dular, the fertility levels in crosses involving the latter were high compared to those of N22 indicating the need for careful selection for 'WC' sources for further utilisation. Pusa 743 is reported to have a 'WC' gene, but in the present study, the cross between Pusa 743 and Akihikari, a typical *japonica* tester had lower spikelet fertility compared to the other cross (Pusa 743/J72) indicating the need to involve a large number of testers in crossing programme. In another set of crosses between

Table 1. Spikelet fertility (%) of F_1 crosses between *indica, japonica* and WCVs

		Indica						Japonica				
Line	Type[a]	IR46 (91.1)	IR36 (89.9)	IR50 (86.9)	IR8 (86.5)	N27 (77.4)	TGMS -	AKR (86.6)	J3 (90.2)	J7 (95.6)	J8 (74.9)	J72 (89.6)
N 22 (89.28)	i							79	80	62	61	90
Dular* (82.53)	i						83-90	86	83	91	78	97
Pusa 743 (88.51)	i							34				75
Pakisan (87.38)	tj	87										
Norin PL9* (86.95)	j		78	85		93	70					
IR 64446* (88.45)	tj			84			70-81			93		
IR 65598* (92.5)	tj			81			91			93		
9310 (80.4)	tj			95			80					
9311 (87.8)	tj			94								
9312 (83.11)	tj		76	79	82		75					
9313 (88.61)	j		36	28			50					
9314* (88.47)	j		86	93	91		91					

TGMS : IR 68945-4-33-14; N 27 - Nagpur 27; AKR = Akihikari

[a]i = *indica*; j = *japonica*; tj = tropical *japonica*

Figures in parentheses indicate spikelet fertility (%) of respective parental lines

* = Promising sources of WC

tropical *japonica* and *indica* (testers), most of the crosses showed normal fertility except those involving 9313. Based on fertility level, the genotypes, Norin PL9, IR 64446, IR 65598 and 9314 were considered most promising sources of 'WC' gene. Besides the crosses made between an *indica* thermo-sensitive genetic male sterile (TGMS) line and tropical *japonica* lines also showed similar results. Since, TGMS line is male sterile at high temperature, it helps in overcoming the problem of hand emasculation while screening for large number of WCVs.

INFLUENCE OF 'WC' GENE

The influence of 'WC' source as male and female on various characters was studied in 28 crosses, where 12 crosses had 'WC' source as male and in 16 crosses WC' parent was used as female. The results are presented in Table 2 and Figure 1(a). It is clear that there are apparent differences between the hybrids depending on the male and female sources of 'WC' gene. Although, the differences were not highly significant, there was a general positive trend, wherein F_1 crosses with male source of 'WC' possessed higher values for all traits including seed yield. To verify the results in direct and reciprocal crosses involving 'WC', three reciprocal crosses were utilised. It is clear from the Figure 1(b), that the source of 'WC' clearly influenced the expression of some traits. The use of 'WC' lines as male source had resulted in significantly higher values for number of spikelets and spikelet fertility, the two major factors affecting grain yield. The differences in respect of other traits were not perceptible. Although it was interesting to see such differences which have major implications in breeding for *indica/japonica* hybrids, there is no mention of such observations in available reports.

HETEROSIS

Data on the evaluation of field performance of *indica/japonica* hybrids is limited. The results of the limited number of studies conducted in Japan and China [2] have revealed that an yield advantage of as high as 43% and 47%, was recorded over the best check variety and the inter varietal hybrid, respectively. In the present study, out of the 40 crosses made, only one cross (IR '8/9312) showed an yield heterosis of 73% (Figure 2) over the inbred check variety **Ajaya**. The hybrid had significantly higher values for panicle length and number of filled spikelets/panicle. The studies conducted in China [8-10] also showed that the number of spikelets/panicle was the major factor contributing to yield heterosis in *indica/japonica* inter sub-specific hybrids.

Table 2. Mean values of F_1 crosses with 'WC' gene as male and female source for various traits

Cross	HT	PN	PL	FS	SFP	TW	SYP
WC source as male parent							
IR 68945/9310	95.0	7.0	24.3	61.5	49.48	3.00	7.60
IR 32364/9310	88.5	14.5	25.8	117.5	83.93	1.90	24.15
IR 36/9311	90.0	6.0	24.8	125.6	75.25	2.33	12.60
IR 8/9312	101	8.0	28.5	282.0	81.74	2.50	44.70
IR 68945/9314	95.0	4.6	24.7	131.4	91.38	2.70	14.00
IR 68945/NPL9	93.0	6.7	24.5	64.0	69.95	2.70	10.30
ID 24/NPL9	93.0	4.6	24.3	80.0	87.34	2.60	7.30
N 27/NPL9	94.0	15	25.0	112.0	93.33	2.30	25.10
IR68945/IR65598	93.0	6.3	24.8	123.0	89.91	2.40	13.60
IR68945/IR64446	**102**	6.0	25.1	113.4	80.66	2.56	14.30
ID 24/IR 64446	87.2	7.2	26.2	156.0	86.96	2.80	18.20
ID24/9314	87.0	6.4	24.6	129.0	87.76	2.40	12.70
Mean	93.23	7.69	25.22	124.62	81.47	2.52	17.05
WC source as female parent							
9310/ID24	80.0	6.0	23.5	133.0	83.13	2.10	13.40
9310/IR 50	88.0	8.8	24.6	129.6	94.60	2.10	14.22
9311/IR 50	83.0	6.8	23.4	130.0	93.53	1.84	8.30
9312/IR 68945	101	5.0	25.0	75.4	50.07	2.88	9.10
9312/IR 36	97.0	5.4	25.3	150.2	75.94	2.88	17.98
9312/IR 50	90.0	6.6	25.9	161.0	79.08	2.44	16.60
9314/IR 36	99.0	7.8	23.8	119.2	85.51	2.40	14.90
9314/IR 50	91.0	6.3	25.5	124.8	92.58	2.40	14.10
NPL9/IR 36	98.0	8.2	24.7	124.4	78.44	3.06	16.10
NPL9/IR50	94.0	6.0	26.0	55.0	84.62	2.50	5.30
IR 64446/IR 50	91.5	11	25.5	127.5	83.61	2.45	19.40
IR 65598/ID 24	98.2	8.4	26.0	149.2	87.66	2.80	23.20
IR 65598/IR 50	92.0	10.6	24.7	157.8	81.01	2.12	23.90
IR 64446/IR 68945	96.0	6.2	25.1	108.6	69.88	2.68	13.44
IR 64446/ID 24	91.0	5.8	26.5	125.8	77.37	2.78	15.46
9314/ID 24	89.0	6.0	25.5	115.5	87.83	2.40	12.50
Mean	92.42	7.18	25.06	124.19	81.35	2.49	14.87

Bold Type : Direct and Reciprocal crosses.

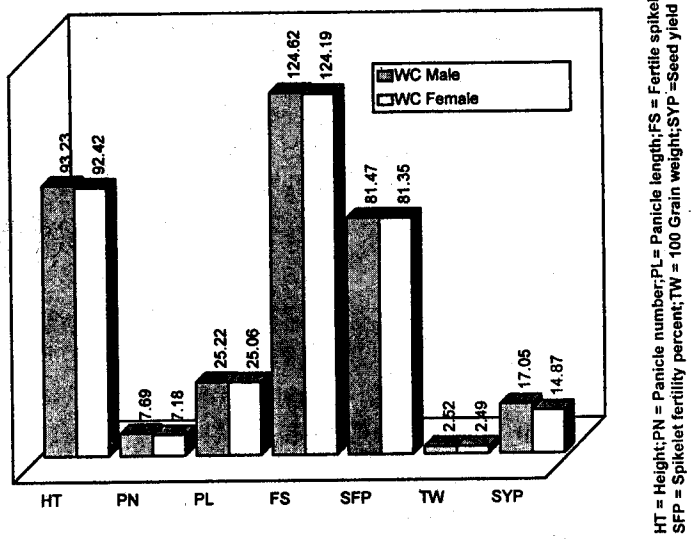

Fig. 1(a). Overall comparison of male vs female as sources of 'WC' gene for yield traits

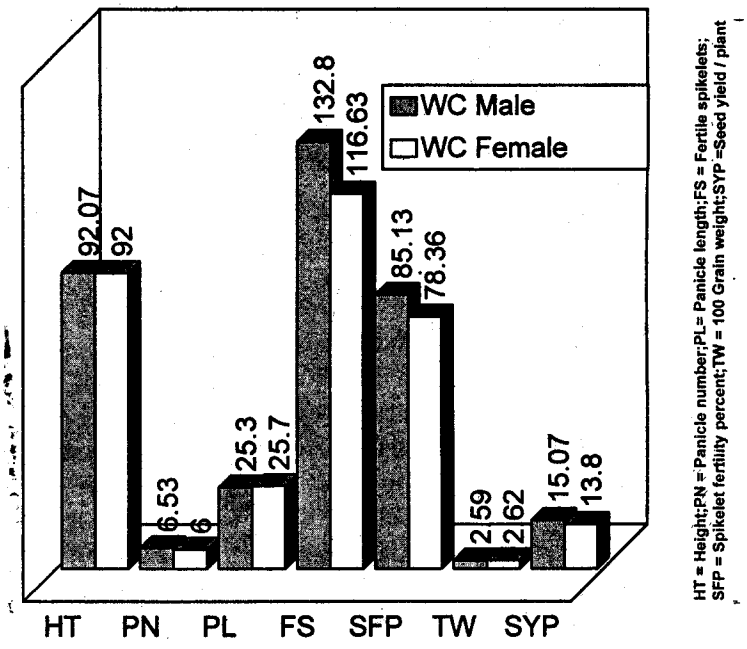

Fig. 1(b). Direct vs Reciprocal comparison of male vs female as sources of 'WC' gene for yield traits

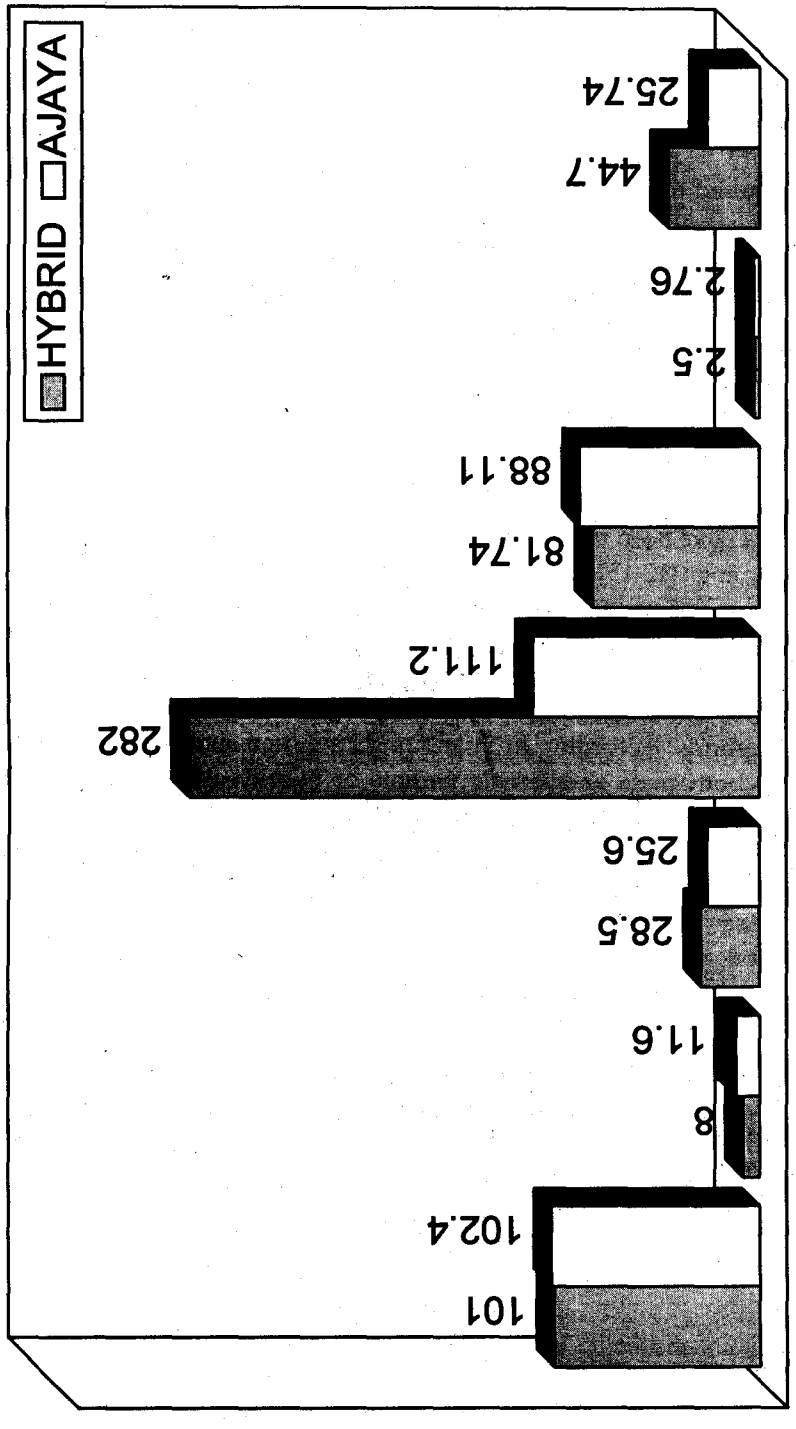

Fig. 2. Heterosis for yield and its components in inter sub-specific hybrids

UTILISATION OF 'WC' GENE

It is desirable to have 'WC' gene in the female lines i.e., CMS lines (for three-line breeding) or TGMS/PGMS lines (for two-line breeding), because in heterosis breeding, male lines are frequently changed unlike their female counterparts. In breeding for *indica/japonica* hybrids suited to tropical conditions, using *japonicas* (temperate/tropical) as female parents is more appropriate as they are poor pollinators when used as male parent. It is reported that natural outcrossing is more in *japonicas* compared to *indicas* (Oka, unpubl.) Kato and Namai [11] also found that most tropical *japonicas* had slender spikelets which often exserted long stigma lobes that contributes to a high outcrossing rate. Frequency of restorer gene(s) is very low in *japonicas*, while wide range of *indica* restorers can be used directly as male parents for *japonica* male sterile (CMS) lines to develop *indica/japonica* hybrids. The occurrence of 'WC' gene also is more widespread in tropical *japonica* than in *indica* and hence development of *japonica* female lines (CMS/TGMS) with 'WC' gene is relatively easier. Meanwhile, wild rice and *indica* rices have been regarded as sources of desirable floral characteristics for seed and pollen parents [12-15]. Additionally the occurrence of fertility restoring gene is more common in *indica* genotypes unlike in their counterpart *japonicas* [16, 17] All these results suggest that *japonicas* (temperate/tropical) should be used as female parents in the development of *indica/japonica* inter sub-specific hybrids. However, our results showed that 'WC' gene in male parent would give desired higher expression of traits in hybrids. According to Yuan Long Ping (personal communication) it is desirable to have both male and female parents of hybrids with 'WC' gene to realise higher heterosis. Then, question arises as to how to breed for *indica* male parents with 'WC' gene. There are two plausible approaches, one to use *japonicas* to transfer 'WC' gene into *indicas* to develop male parents and the second is to use *indica* source to transfer 'WC' gene. In the first approach, by using *japonica*, it is likely that male parents finally developed would contain genes from *japonica* by which their relatedness to *japonica* female parents will be closer and thereby the magnitude of heterosis may be reduced, and it is also expected that the desirable floral characteristics of pollen parent may get affected in the male parents. Therefore, the second approach seems to be more appropriate, where, WCVs that are most related to *indicas* should be used. It is suggested that use of WCVs such as 'Dular' which has been confirmed by many workers including Ikehashi [5] as good source of 'WC' gene should be used for developing *indica* male parents carrying 'WC' gene.

Broad conclusions that can be derived from the present study are :

(i) While screening for the presence of 'WC' gene, it is desirable to use atleast 4-5 tester genotypes to get reliable results.

(ii) In breeding for *indica/japonica* inter sub-specific hybrids, it is desirable to have 'WC' gene in both male and female parents. It is suggested that *japonicas* (tropical or temperate) should be used as female, while *indicas* as male in the development of inter sub-specific hybrids. The *indica* male parents (restorers) possessing 'WC' gene should be developed by incorporating 'WC' gene from *indica* sources like Dular.

(iii) Higher heterosis in inter sub-specific hybrids results from increased number of fertile spikelets/panicle.

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