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Screening of potential donors for development of new plant types in irrigated rice (*Oryza sativa*) in eastern India

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ABSTRACT

Enhancing the yield potential of irrigated rice would be the key for meeting the global as well Indian rice requirement. There is more or less stagnant yield potential of semi-dwarf indica inbreeds observed since release of IR-8. New plant type is one of the potential approaches for raising yield ceiling in irrigated ecology. Tropical japonicas (Javanicas) are supposed to be the potential donors, for broadening genetic base, because of their heavy panicle size (with large number of spikelets) and stiff straw. 225 Tropical japonicas (TJ) and their derivatives (including few Assam Rice Collections) were screened for super plant type traits to be utilized as prospective donors. Variability study for the parameters viz., number of grains/panicle, plant height; tiller number and test weight exhibited comparatively higher phenotypic as well as genotypic coefficient of variation. The characters, test weight, plant height and days to flowering were recorded as highly heritable, whereas, specific leaf weight, culm strength and flag leaf angle as moderately high. On the basis of estimates h^2 and GA, the traits viz., plant height, flag leaf angle, culm strength, specific leaf weight and 100 grain weight could be regarded more amenable to selection. A suitable combination of desirable characters should have to be taken up, to do away with the bottlenecks for designing a NPT. TJ derivatives CR-2667-9-1, CN-65-5 and CR-780-1937-1 were found with lodging resistance along with moderate to high tillering (7.5 -12.0). Genotypes CR-2667-11-1-2-1, CR-2688-6-7, CR-2667-8-2, TCA-282, CR-2672-13-1-1, CR-662-2211-1-1-5/7 and AC-38693-1 were recorded with heavy drooping panicle and high grain number, whereas, CR-2667-9-2-6 and CR-780-1937-1 with long panicle (34.0 cm), TCA-282 and CN-65-5 were with high tillering along with heavy panicle. Similarly, CR-2672-13-1-1, CR-662-2211-1-1-5/7 were observed with long upright thick top leaves (Avg. leaf length 46.0 cm); CN-65-5 and CR-2687-16-4-1 were found with good grain filling and were identified to be prospective donors. These could be hybridized with IR 73943-120-5-3-2, IR-1700-247-5-3-2-1, IR-72158-154-3-2-1-1-1, IR-73933-8-2-2-3 and IR-73107-45-3-2-3 or Swarna (MTU-7029) as female parent for development of NPTs with high grain yield coupled with tolerance to major diseases and pests.

Key words: Grain yield of rice, new plant type, tropical japonica

Rice is a staple food of the largest number of people and a majority of them are poor. India has a current estimated growth rate of 1.18% in its productivity but it might become a net importer by 2020 in case it fails to maintain 1.75% per annum growth for next 10 years (Anon, 2009). There is increasing competition for water and other resources because of increased population coupled with higher industrialization and urbanization and diversion of agricultural land. As irrigated rice contributes more than 75% of the total rice production, enhancing its yield potential would be the key to meeting Indian as well as global rice requirements. There is more or less stagnant yield potential of semi-dwarf *indica* inbreeds observed since release of IR-8. There are several approaches for raising yield ceiling in irrigated ecology. 'New plant type' is one of the potential approaches.

The average yield of irrigated rice varieties has to increase from 5.0 to 8.5 tons/ha. For these rice varieties with an yield advantage of 20% over widely grown varieties must be developed. Therefore, development of a new plant type for irrigated ecology, tolerant to major biotic and abiotic stress, is one of the major challenges that has to be addressed in near future.

Improving rice yield potential was the main breeding objective since 1950s. Tropical varieties of prodigious yielding capacity *viz.*, Jaya in India and Bg. 90-2 from Sri Lanka followed by Tongil-type rice varieties in Korea in 1971, from a *japonica/ indica* hybridization, showed a 30% yield increment compared to japonica genotypes (Chung and Heu, 1980). Similarly, in 1982, the super-high-yielding rice breeding program in Japan produced several promising super-high-yielding cultivars such as Akenohoshi and Akichikara. These varieties are panicle-weight type with a large number of spikelets per panicle (Wang *et al.*, 1997). In 1966, IR8, the first semi-dwarf, high-yielding modern rice variety, was released for the tropical irrigated lowlands (Khush *et al.*, 2001). The birth of IR8 increased the yield potential of the irrigated rice crop from 6 to 9.5 t ha^{-1} in the tropics (7.5–8.0t ha^{-1} now under the best management, Peng *et al.*, 1999). However, stagnant yield potential of semi-dwarf inidica inbreds observed since the release of IR8 .It was postulated that this stagnation might be the result of the plant type having high tillering capacity and small panicles, unproductive tillers, limited sink size and lodging susceptibility. Again, these have excessive leaf area that may cause mutual shading and a reduction in canopy photosynthesis and sink size, especially when grown under direct seeded conditions (Dingkuhn *et al.*, 1991). With this backdrop, IRRI scientists proposed "New Plant Type" to break the yield potential barrier, modifications to the high-yielding *indica* plant type in the late 1980s and early 1990s with a goal to develop a genotype with 30-50% higher yield potential than the existing semi dwarf varieties in tropical environments during the dry season (Khush, 1995).Combination of *indica*s either with

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indicas or *japonicas* was not highly successful in getting a good ideotype raising yield ceiling. At this juncture, *Tropical japonicas* came to rescue for development of New Plant Types (NPTs). IRRI developed an NPT *i e.*, IR 72967-12-2-3 with a productivity of 10.16 t ha^{-1} along with few others. However, those NPTs do not perform as per expectation in eastern India in particular and India in general (around 6 t ha^{-1}). It necessitates the indigenous development of NPTs. Tropical *japonicas* (*Javanicas*) are supposed to be the potential donors for the above purpose because of heavy panicle size (with large number of spikelets) and stiff straw with high specific leaf weight. However, these are associated with number of other undesirable characters *viz.*, tall, lodging susceptible, along with low tiller number. Therefore, a suitable combination of desirable characters should have to be taken up to do away with the bottlenecks for designing a NPT with following rationale:

i. Yield is a function of total dry matter and harvest index (H.I.). Therefore, yield can be increased by enhancing the total dry matter or harvest index or both. The H.I. can be increased by increasing the sink size. e.g., we can raise the number of grains per panicle. On the other hand, we need to develop plants with sturdier stems so that nutrients can be applied at higher rates to enhance total biomass.
ii. The choice of traits to breed for an ideal plant type for the irrigated lowland came from several different perspectives. Combination early vegetative growth, high tillering, few unproductive tillers, Semi dwarf plant height, moderately large panicles, grain-filling percentage, erect and long top three leaves and , growth duration of 100-130 days, and tolerance to disease and insect.
iii. Selection of donors with ideal for single or multiple ideal traits for greater quantum yield and here sink is the key factor.

Hybridization of donors with ideal individual or multiple cross will result in culmination of traits leading to the new plant type (ideotype). Hence, identification of donors with the above desirable traits and introgression of important genes into a desirable recipient would be the appropriate strategy.

MATERIALS AND METHODS

Screening for donors

Two hundred twenty five genotypes including *Tropical japonicas* (TJ), derivatives of TJ (purelines developed after cross of *TJ* with *indicas* with comparable maturity duration), Assam Rice Collections (ARC) collected and stored at CRRI gene bank, and other exotic and indigenous collections were planted in Augmented Block Design with four checks (Annada, Naveen, IR-64 and Swarna) during wet season of 2009 at Research Farm, Central Rice Research Institute, Cuttack.

Screening for Recipients

Thirty six NPTs developed at IRRI (Table. 1) were evaluated for grain yield and other morpho-physiological traits during dry season of 2009-10 with Randomized Complete Block Design with two replications with three popular varieties as checks (Annada, Naveen and IR-64). This was because the *Tropical japonicas* were mostly photo-sensitive and normally flowers in wet season, whereas, the dry season is ideal for testing NPTs. The seeds were sown in nursery bed and transplanted after 25 days in puddled field with a spacing of 20 cm × 20 cm during both the seasons. Recommended agronomic practices were followed to maintain a healthy crop. Five competitive plants in each line (and from each replication in case of NPTs) were selected randomly and different morpho-physiological characters supposed to be important for grain yield and yield attributing traits were studied. Observations were recorded for traits *viz.*, days to 50% flowering, plant height (cm), panicle length (cm), no. of tillers, no. of grains $panicle^{-1}$, 100 grain weight (Test weight) using standard procedure. Flag leaf erectness and culm strength was recorded following Standard Evaluation System (Anon, 1996) for the donors. Specific leaf weight was calculated by dividing the dry leaf weight (g) by its area (in m^2) (Bondada and Oosterhuis, 2001).In case of NPTs only grain and yield attributing traits were recorded (Anon, 1996).

RESULTS AND DISCUSSION

To break the yield ceiling, several approaches are being explored. These include development of a new plant type (NPT) with low tillering capacity and large panicles from tropical japonica germplasm and exploitation of heterosis through inter-sub specific and inter-varietal hybrids (Peng *et al.*, 1999). Designing NPTs has passed several phases *viz.*, 1^{st} generation NPTs, 2^{nd} generation NPTs and China's super hybrid rice programme. The new design focuses on moderately large panicle size with 150 grains, sturdier stem so that the plants would not collapse under heavy loads of grains, dark green, thick (with high specific leaf weight of about 55 g m^{-2}), erect and long top three leaves, moderate tillering capacity (270-300 panicle m^{-2}), moderately heavy (5g) and drooping panicle at maturity, plant height of 110cm and a harvest index of 0.5 5(Peng *et al.*, 2008). It was expected that harvest index could be improved with increased sink size and few unproductive tillers. Other common traits are erect-leaf canopy and slightly increased plant height in order to increase biomass production. NPT necessitates systematic accumulation of some of the genes lacking in the parents already adapted or developed. Screening is the process of selecting the desirable ones from the population and assessment of variability is the primary step. Adequate genetic variability indicates sufficient scope for genetic improvement of the traits.

Analysis of variance revealed significant difference among the fixed lines for all the traits under study, indicating, sufficient variability and further possible response to selection in breeding programme among the TJ and other parents (donors).The block effect were significant for all the morpho-physiological traits except flag leaf angle and specific leaf weight indicating less sensitivity of the materials to environment for the characters. Similarly, significant difference was also recorded among the developed NPT lines indicating sufficient scope of selection and their further exploitation.

Table 1: Name and designation of the new plant types with checks

Name	Designation	Name	Designation	Name	Designation
NPT 1	IR-1700-247-5-3-2-1	NPT 2	IR-72158-154-3-2-1-1-1	NPT 3	IR-72158-68-3
NPT 4	IR-73933-106-2-1-2-2	NPT 5	IR-73971-87-1-1-1-1	NPT 6	IR-72158-148-4-2-6-2
NPT 7	IR-71701-28-1-4	NPT 8	IR-73107-45-3-2-3	NPT 9	IR-73930-41-5-3-1
NPT 10	IR-74714-141-3-3-2-4	NPT 11	IR-73898-71-2-6-3	NPT 12	IR-73931-40-9-2-3-2
NPT 13	IR-73930-31-3-2-2	NPT 14	IR 78629-57-3-3-9	NPT 15	IR-72164-186-5
NPT 16	IR-72164-186-5	NPT 17	IR-72058-26-3-2-3	NPT 18	IR-73933-8-2-2-3
NPT 19	IR-74158-72-3-2-10	NPT 20	IR 73995-13-1-3-2	NPT 21	IR 72158-148-2-6-2
NPT 1(PS)	IR 73895-33-1-3-2	NPT 2(PS)	IR 73933-8-2-2-3	NPT 3(PS)	IR 73896-51-2-1-3
NPT 4(PS)	IR 73943-120-5-3-2	NPT 5(PS)	IR 75163-45-2-5-3	NPT 6 (PS)	IR 73931-40-1-2-3-2
NPT 7(PS)	IR 75282-58-1-2-3	NPT 9 (PS)	IR 75279-43-2-1-3	NPT 11 (PS)	IR 73973-27-1-1-2
NPT 13 (PS)	IR 73963-86-1-5-2-2	NPT 14 (PS)	IR 73907-753-2-3	NPT 16(PS)	IR 72967-12-2-3
NPT 17 (PS)	IR 72969-143-5-3-6	NPT 18 (PS)	IR 73896-51-2-1-3	NPT 20 (PS)	IR 72176-140-1-2-2
NAVEEN	-	ANNADA	-	SWARNA	MTU-7029
IR 64	-				

Table 2: Overall mean performance of donors, their range, mean, PCV, GCV, heritability and genetic advance as % of mean

Character	Range	Mean	GCV	PCV	Heritability	G.A. as % of mean
Days to flowering	124.3-165.7	148.21	8.76	9.32	91.85	17.60
Plant height	107.4-186.5	157.17	20.39	22.09	94.67	43.07
Panicle length	19.2-36.3	22.4	8.51	9.78	74.83	15.06
Flag leaf angle	1.0-6.8	3.2	12.32	13.94	80.67	22.85
Tiller number	4.5-13.0	6.6	16.56	20.49	67.11	28.32
No. of grains panicle^{-1}	112.6-403.3	155.5	25.81	27.98	72.73	41.98
Culm strength	2.65 – 6.60	4.2	13.27	14.48	81.43	24.29
Specific leaf weight	4.6 -6.4	50.5	11.39	12.88	84.25	22.35
Test weight	1.92 – 3.52	2.58	18.45	19.03	95.47	37.43

Estimates of genotypic and phenotypic coefficient of variation (in donors) indicated that in general, magnitude of PCV was higher than GCV for all the characters, indicating a positive effect of environment on the character expression. The variances were compared on the basis of coefficient of variations. The parameters number of grains/panicle, plant height; tiller number and test weight exhibited comparatively higher estimate of phenotypic as well as genotypic coefficient of variation (Table 2).It indicated the effectiveness of simple selection for these traits. This was in agreement with earlier report of Subudhi and Dikshit (2009) and Das *et al* (2001).Therefore, screening and selection of *TJ* genotypes may be effective. In an augmented design, the error variance is inflated and thus, may not able to have better precision of variation with GCV and PCV alone, therefore the estimate of heritable variation (heritability) along with genetic advance (as % of mean) is more meaningful. Since, in augmented design, only the error variance of check varieties could be subtracted from the variance of genotypes, a portion of it may be confounded with genotypic variance in calculating heritability (h^2), therefore , caution should be exercised in interpreting the 'h^2' as they represent the upper limit (Singh et al., 2009). In the present investigation 'h^2' were of higher magnitude (>50%) for all the characters studied. However, the characters, test weight, plant height and days to flowering were recorded as highly heritable and specific leaf weight, culm strength and flag leaf angle as moderately high. It indicated that selection for these traits is repeatable. Similar observations were reported by Subudhi and Dikshit (2009). Heritability along with genetic advance as % of mean (GA) are more helpful in predicting genetic gain under selection than heritability alone (Sinha, *et al.*, 2004). Therefore, on the basis of estimates h^2 and GA, the characters *viz.*, plant height, flag leaf angle, culm strength, specific leaf weight and 100 grain weight could be taken as characters more amenable to selection in relation to others. Similar reports of Singh *et al.*, 2009 support the present findings.

Table 3: Promising genotypes with highly desirable characters (highlighted) as prospective donors

Donor / Designation	Days 50% fl.	Plant ht (cm)	Panicle length (cm)	Flag leaf erect ness	Tiller	Culm strength	Specific leaf weight	No. of grains	Test weight	Other characters
CR-2695-15-3	135	136	25	3.1	6	2.7	61.3	413	3.52	Very sturdy culm
EC-491336	136	115	23	2.1	5.5	3.0	55.4	136	2.74	-
CR-2667-9-1	135	128	24	1.1	10	2.95	60.7	150	2.75	Non lodging
CR-2687-13-4-1	163	137	27	1.0	9	3.5	62.7	212	2.64	Ideal plant type
CN-65-5	144	165	29	1.0	12	6.0	61.8	386	2.48	Good grain filling
CR-2667—11-1-2-1	163	160	31	1.2	4.5	6.0	54.8	393	2.69	Dense and wider flag leaf
CR-2688-6-7	151	165	28	1.0	5.5	6.7	57.4	348	2.74	Drooping, heavy panicle
CR-2667-8-2	148	162	35	1.0	8	5.1	56.2	391	2.96	Heavy panicle
TCA 282	144	165	32.5	1.3	12	4.0	55.7	379	2.69	Very promising
EC-491223	150	169	34	3.1	6	5.4	53.2	278	3.11	Very bold grains
CR-2672-13-1-1	139	169	27	1.2	4.5	4.8	57.7	376	2.72	Heavy panicle
AC-38693-1	146	168	28.5	1.4	7	4.3	54.8	345	2.89	-
CR-2687-17-3-1	135	178	22.7	5.0	5.5	2.6	47.3	339	3.27	-
EC-491324	156	183	24	1.4	6	5.2	55.6	302	2.87	Wider flag leaf heavy drooping panicle
AC-38606	152	140	25	3.4	14	5.2	48.4	177	2.72	Lodging susceptible
CR-2682-13-2-11-4-1	158	135	27	1.2	13	3.0	54.3	346	2.58	-
AC-38724	141	176	30	3.6	11	6.6	46.9	254	3.09	Heavy panicle, golden yellow col
CR-2667-13-2	159	169	25	1.2	12.5	4.6	56.3	209	2.51	-
CR-2687-16-4-1	159	146	26	1.1	11	3.5	54.1	196	2.70	Good grain filling
IR-84649-308-24-1-B	135	125	25	1.3	8	1.6	57.3	161	2.24	Wider flag leaf, long medium fine grains
ARC-15	106	123	25	1.6	7	1.8	55.2	206	2.41	Broad, upright flag leaf, moderately heavy panicle
CR-2667-9-2-6	135	157	34	3.6	6.5	3.6	43.4	305	2.78	-
CR-780-1937-1	134	107	34	1.0	7.5	1.2	63.1	314	3.05	Erect, potential donor
Ac-38582	144	186	33	1.6	6	3.12	54.4	285	3.12	Erect
CR-662-2211-1-1-5 derivative	131	108	29	1.1	6	1.3	56.2	276	2.71	Avg leaf length: 47.5 (top 3 leaves)
CR-662-2211-1-1-7 derivative	124	103	28	1.1	7	1.3	56.1	315	2.79	avg leaf length: 44.5(top 3 leaves)
CR-662-2211-1-1-54 derivative	132	116	30	1.2	6	1.3	53.4	172	2.69	Avg leaf length : 54.4 (top 3 leaves)
AC-38999	151	175	27	1.2	5.5	1.6	53.2	226	3.27	Very good grain filling
CR2682-7-1	153	139	26	1.2	9.8	2.2	59.3	305	2.59	-
Gayatri x GP-445	154	172	27	1.15	10	3.1	57.6	262	2.73	-
Gayatri x GP-445	160	171	22	1.2	8.5	3.6	58.0	293	2.59	-
SWARNA MTU 7029	123	118.4	25.2	1.2	10.2	1.2	56.2	164	2.23	-
NAVEEN	98	121.9	27.3	3.1	9.6	1.6	49.8	124	1.84	-
ANNADA	88	85.1	21.2	1.6	7.1	1.2	52.6	109	2.19	-
IR-64	94	92.1	25.3	1.2	7.5	1.1	53.8	142	2.01	-
LSD(0.05)	**4.51**	**8.24**	**2.94**	**1.10**	**2.56**	**1.62**	**2.71**	**26**	**0.84**	-

The objective of this study was to screen donors for suitable combination with indica or indica like recipients and broaden the genetic base in order to increase heterosis or potential transgressive segregants. The entire set of genotypes (donors) was screened, either for single or multiple traits irrespective of their grain yield. The suitable few genotypes with better potential have been presented in table-3 along with the checks. In relation to individual traits, however, some of them could be utilized for trait specific complementation. Most of the donors were of long duration type; however, breeding lines CR-662-2211-1-7 and CR-662-2211-1-5, being medium maturity, could be utilized when duration needs reduction. Similarly, most of the tropical japonicas were of tall type and might create problem in selection when hybridized with a dwarf recipient, hence a dwarf type would be ideal. In this context, lines EC-491336, CR-780-1937-1, CR-662-2211-1-1 -5/7/54 having height less than 115 cm could be utilized. Long panicle trait being a desirable trait, CR-780-1937-1, CR-2667-8-2, EC-491223 and CR-2667-9-2-6 may be suitable for enhancing panicle length (34.0 cm). There were number of genotypes having erect flag leaf, however, CR-2687-13-4-1, CR-65-5, CR-2688-6-7, CR 2667-8-2 and CR-780-1937-1 were prominent among them. AC-38606, CR-2682-13-2-11-4-1, CR-2667-13-2, TCA-282 and CN 65-5 were observed with high tiller number. CR-780-1937-1, CR-662-2211-1-1 derivatives, AC-38999, IR-84649-308-24-1-B and CR-2695-15-3 were recorded with high culm strength. CR-2695-15-3, CR-2667-9-1, CR-2687-13-4-1, CR-780-1937-1 (*TJ* derivatives) and CN-65-5 and were found with high specific leaf weight along with moderate to high tillering (6.0 - 12.0) under space planting. Genotypes CR-2667-11-1-2-1, CR-2688-6-7, CR-2667-8-2, TCA 282, CR-2672-13-1-1 and AC-38693-1 were recorded with heavy drooping panicle and TCA-282 and CN-65-5 were with high tillering (10-12) along with heavy panicle. Long upright thick top three leaves, with flag-leaf length of 50 and 55 cm for the 2nd and 3rd leaves(all three leaves are above panicle height) are considered important in super rice ideotype (Peng, 2008), therefore, CR-2672-13-1-1 and CR-662-2211-1-1-5/7 were considered promising (Avg. leaf length 46.0 cm).

Grain number being one of the most important trait, the genotypes CR-2695-15-3, CR-2667-11-1-2-1, CR-2667-8-2, TCA 282, CR-2672-13-1-1, CR-2688-6-7, CR-2682-13-2-11-4-1, AC-38693-1, CR-2687-17-3-1, CR-662-2211-1-1-7 and CR-780-1937-1 recorded with high grain number were considered important. Likewise, CN-65-5 and CR-2687-16-4-1 were having good grain filling. Most of the tropical japonica derivatives (and other donors) were having bold grains but, some of them were medium bold viz., CR-2695-15-3, CN-65-5, CR-2667-13-2, IR-84649-308-24-1-B, ARC-15 and hence could be easier for selecting grains with acceptable quality. However, considering multiple traits, CR-2695-15-3, CR-2667-8-2, CR-2688-6-7,CR-2667-11-1-2-1, TCA 282, EC-491223, CR-780-1937-1, CR-2672-13-1-1 and CR-662-2211-1-1-5/7 were found potential and may be choosen as prospective donors.

Table 4: New plant types and their agronomic characteristics

Genotypes	Flowering (days)	EBT	Height (cm)	Panicle length (cm)	Grain Yield (t ha^{-1})	% increase over best check
IR 73943-120-5-3-2	108	9.0	109	33.1	6.20	39
IR-1700-247-5-3-2-1	111	10.8	99	27.3	5.95	33.7
IR-72158-154-3-2-1-1-1	108	9.4	93.6	29.2	5.62	26.29
IR-73107-45-3-2-3	107	9.6	102.0	28.1	5.29	18.87
IR 78629-57-3-3-9	115	9.2	86.3	28.0	5.21	17.07
SWARNA	130	9.8	106	27.5	5.77	29.66
NAVEEN	102	8.5	113.0	26.0	3.96	-
ANNADA	99	8.4	82.4	23.5	3.82	-
IR-64	104	8.6	91.3	26.8	4.45	-
SEM(±)	**1.04**	**0.63**	**2.76**	**1.26**	**0.36**	-
LSD(0.05)	**3.07**	**1.82**	**7.86**	**3.01**	**1.01**	

Among developed NPT lines (Table 4), IR 73943-120-5-3-2 and IR-1700-247-5-3-2-1 were found to be superior genotypes with high grain yield with 6.20 and 5.95 tonnes ha^{-1} respectively. These were followed with IR-72158-154-3-2-1-1-1, IR-73933-8-2-2-3 and IR-73107-45-3-2-3 with appreciable grain yield and other morpho-physiological and disease and pest tolerating traits. Similarly another popular *indica* variety Swarna (MTU-7029) could also be effectively utilized as female parent for cross combination with *TJ*s or their derivatives for development of NPTs suitable for eastern India with high grain yield coupled with tolerance to major diseases and pests.

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