CULTIVAR RELEASE

CR Dhan 407, a high-yielding rice cultivar released for the rainfed shallow lowland ecosystem of eastern India

P S Roy[1], S S C Patnaik[1*], A Patnaik[1], G J N Rao[1] and O N Singh[1]

Abstract – *Development of high-yielding rice varieties for the rainfed shallow lowland ecosystem of eastern India is a major challenge for plant breeders. Development and release of CR Dhan 407, a high-yielding cultivar, with a potential yield of more than 5 tons per hectare and non-lodging plant type, can address the problem of yield stagnation in this major rice ecosystem of India. With its high yield and excellent grain quality, this variety can significantly enhance the income of rice farmers of eastern India.*

Key words: *Rice, breeding, variety, multi-location, fingerprinting.*

INTRODUCTION

Rice (*Oryza sativa* L.), the staple food crop of millions, contributes 27 per cent of dietary energy supply, 20 per cent of dietary protein and 3 per cent of dietary fat in the Asian Diet (FAO 2002). For most rice-producing countries to attain self-sufficiency, development of high-yielding rice varieties with consumer-preferred grain quality features and inbuilt resistance against diseases and insect pests to safeguard the environment is a prerequisite.

In India, 92% of an area of about 12 million hectares of a rainfed lowland ecosystem (Reddy et al. 2013) is distributed in the eastern and northeastern states (Singh and Hossain 2000). Though eastern India comprises the largest rice-growing region of the country (58%), both production and productivity are the lowest, with an average productivity of only 1.0 - 1.2 t ha^{-1} (Adhya et al. 2008). Since these lowlands are rainfed, rice production suffers due to the vagaries of the monsoon rainfall and water stagnation up to 50 cm in the rice fields is a common feature (Singh 2006). Until recently, rice cultivation in the rainfed ecosystems of eastern India was restricted to growing traditional varieties. They are characterized by tall plant types prone to lodging, unresponsive to fertilizer inputs, and generally low yielding. Hence, farmers are unable to get high economic returns. Development of improved cultivars for the rainfed shallow lowland ecosystem may lead to a quantum leap in national production and economic returns to farmers since this is

one of the major rice ecosystems in India. In developing high-yielding varieties for a target ecosystem, traits related to yield stability and sustainability are the major focus of plant breeding efforts (Fehr 1987, Falconer and Mackay 1996, Cutforth et al. 2007, Naylor 2007, Araus et al. 2008, Collard and Mackill 2008, Soares et al. 2013, Neto et al. 2013). To address problems like the low and highly unstable yields of this ecosystem, a systematic breeding approach was undertaken at the ICAR-Central Rice Research Institute, India. The present study reports the development of a high-yielding variety suitable for the rainfed shallow lowlands of eastern India using the pedigree breeding approach.

MATERIAL AND METHODS

Development of breeding populations and field evaluation of promising lines

The parents employed in the study were two mega-varieties: Swarna, a variety released (1982) for rainfed shallow lowlands of India, and IR64 [developed at the International Rice Research Institute, Manila and released in several countries, including India (1992)]. The breeding populations were generated using the pedigree method (Figure 1).

A total of 1080 single plants of semi-dwarf plant stature were selected from the 3,000 plants grown in the F_2 generation from the fifteen F_1 hybrid (Swarna/IR64) plants. From the F_3 generation, the lines were selected based on duration,

[1] Crop Improvement Division, Central Rice Research Institute, Cuttack (753006), Odisha, India. *E-mail: sasank.crri@gmail.com
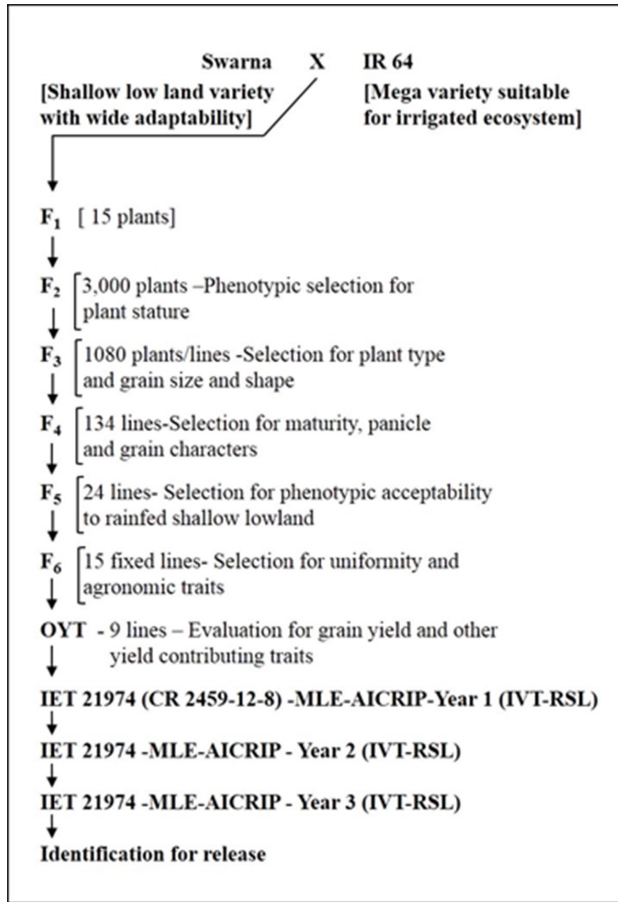
Figure 1. Breeding scheme illustrating the development of IET21974 (CR 2459-12-8). MLE-Multi-location evaluation; RSL – Rainfed Shallow Lowland; IVT-Initial Evaluation Trial. AICRIP- All India Coordinated Rice Improvement Programme

panicle type, and grain traits, and only plants/lines having a semi-dwarf plant stature and Swarna type grain were advanced. Selection was continued up to the F_6 generation until nine fixed lines with desirable features were identified.

For the observational yield trial (OYT), thirty-day-old seedlings of the nine selected lines and the parents were transplanted in a well-prepared field at a 15 x 20 cm spacing in a randomized complete block design with two replications at the experimental farm of the Central Rice Research Institute (CRRI), Cuttack. The crop was moderately fertilized (N:P:K; 60:40:40 kg ha^{-1}) and plant protection measures were undertaken according to need. Observations were recorded for five plants for agronomic traits, and grain collected from a 1 m^2 area from each replication was taken to estimate the yield.

Multi-location evaluation

The most promising recombinant line (CR 2459-12-8) identified from the observational yield trial was nominated for the multi-location evaluation trials, conducted by the All India Co-ordinated Rice Improvement Programme (AICRIP), the nodal (Government) agency designated in India for the purpose of evaluating breeding lines prior to their release. The line was evaluated for three consecutive years (2010-2012) in the trials conducted in the rainfed shallow lowland ecosystem (RSL) with the designation IET 21974.

DNA fingerprinting

Genomic DNA was extracted from young rice leaves as per Dellaporta et al. (1983). For DNA fingerprinting analysis, rice microsatellite markers (McCouch et al. 2002, Singh et al. 2010) representing all twelve chromosomes were used. All the PCR assays were performed as described earlier for each marker, and the separated PCR products were visualized under UV light and photographed using a Typhoon FLA 7000 fluorescent image analyzer (GE Healthcare Bio-Sciences AB, Uppsala, Sweden).

RESULTS AND DISCUSSION

Performance

The observational yield trial (OYT), conducted with nine selected breeding lines for their agronomic performance, resulted in identification of two promising lines, CR 2459-12-8 and CR 2459-12-18, and both lines out-yielded the parents (Table 1). Of the two promising lines, CR 2459-12-8 was identified for further evaluation as it has the desirable grain quality traits of Swarna, the most popular rice variety in India.

Table 1. Agro-morphological features of the promising breeding lines

Genotypes	PH (cm)	DFF (days)	PL (cm)	EBT	YD (t ha^{-1})
Swarna	106.3	115	24.2	229	3.9
IR 64	92.7	92	27.2	259	4.8
CR 2459-10-2	122.7	116	27.4	260	4.6
CR 2459-14-21	119.2	120	28.0	227	3.8
CR 2459-1-3	116.7	125	21.2	249	3.8
CR 2459-7-6	125.5	121	26.8	238	3.2
CR 2459-7-12	120.8	118	29.5	197	3.8
CR 2459-5-4	116.5	119	25.1	209	3.0
CR 2459-9-16	114.5	125	26.1	274	3.9
CR 2459-12-8*	112.5	117	28.3	266	5.5
CR 2459-12-18	116.5	122	26.5	264	4.8
CD 5%	1.96	1.89	4.26	39.29	1.23
CV	1.0	0.9	9.5	9.5	17.6

PH- Plant height; PL- Panicle length; DFF- Days to fifty per cent flowering; EBT- Ear bearing tillers; YD- Yield * - Line proposed for release

Multi-location evaluation

In the first year of testing (2010) in the multi-location trials, IET 21974 (CR 2459-12-8) was ranked 1st among the 42 entries, recording a mean yield of 5093 kg ha^{-1}, and on an overall mean yield basis, it showed 16.5%, 29.0%, and 42.3% yield superiority over the national, regional, and local control varieties, respectively (Table 2). In the state of Odisha and West Bengal, it was ranked first, with mean yield of 5030 kg ha^{-1} and 5219 kg ha^{-1}, respectively (Table 3). In the year 2011 (2nd year), it was ranked 2nd (5024 kg ha^{-1}) on an overall mean basis and out-yielded the national (24.3%), regional (32.5%), and local (13.2%) controls on an overall mean basis (Table 2). The entry IET 21974 also showed superior performance in different states like Odisha (2nd rank, 5488 kg ha^{-1}) and West Bengal (2nd rank, 5437 kg ha^{-1}) and showed 20.96% and 15.87% yield superiority, respectively, over the best control in those states (Table 3). In 2012 (third year), IET 21974 was ranked 1st (5517 kg ha^{-1}) on an overall basis and again surpassed the controls (Table 2). It was ranked first in the states of West Bengal (6665 kg ha^{-1}) and Assam (5815 kg ha^{-1}) (Table 3). From the three year pooled data, IET 21974 had a mean yield of 5211 kg ha^{-1} and recorded 18.5% yield superiority over the national control (Dhanrasi), 29.8% over the regional control (Swarna Sub1), and 17.4% over the local control (Directorate of Rice Research 2011, 2012, 2013).

The line IET 21974, with a plant height of 102 cm, duration of 150 days, and well-exerted compact panicles, consistently recorded superior performance and yield superiority over the controls, with a yield potential >5 t ha^{-1} in all three years of evaluation. It showed moderate resistance to bacterial blight, leaf blast, white backed plant hopper and whorl maggot. This line was also found to be highly responsive to fertilizer application and responds well up to 130 kg ha^{-1} of N. The line CR2459-12-8 possesses desirable grain quality features like long grain, high head rice recovery - HRR (63.6%), intermediate amylose content (23.475%), and intermediate gel consistency - GC (Table 4). Based on its overall performance in the multi-location trials of AICRIP from 2010-2012, IET 21974 was identified as promising and released as CR Dhan 407 for the rainfed shallow lowland ecosystem of the states of Odisha and West Bengal in India in 2013.

DNA fingerprinting

The DNA fingerprint pattern generated using twenty-four rice polymorphic microsatellite markers suggests that allele sharing between CR 2459-12-8 and Swarna was 54.2%, while the sharing was 45.8% between CR 2459-12-8 and IR 64, thus establishing the lineage of CR 2459-12-8 with its parents (Figure 2). The unique fingerprints of CR 2459-12-8 can be used for its easy identification and protection of intellectual property rights.

As only a limited number of rice varieties with good grain quality and superior grain yield potential are available for the farmers in this ecosystem of eastern India, yield gains have not yet been very extensive. In this context, the variety CR Dhan 407 can be a boon, with desirable features like semi-dwarf stature, non-lodging plant type, late maturity period, and dark green leaves that are ideal for shallow lowlands. Release of this variety is an important step towards

Table 2. Performance of IET 21974 (CR 2459-12-8) in the multi-location trials (2010-12)

Year	IET 21974	NC	RC	LC
2010	5093	4372 (16.5)	3947 (29.0)	3578 (42.3)
2011	5024	4042 (24.3)	3792 (32.5)	4437 (13.2)
2012	5517	4780 (15.4)	4309 (28.0)	5301 (4.1)
Mean	5211.3	4398 (18.5)	4016 (29.8)	4438.7 (17.4)

NC- National control (Dhanrasi); RC- Regional control (Swarna sub 1); LC- Local control. Figures in parentheses indicate % increase of IET 21974 over the control.

Table 3. Performance of IET21974 (CR 2459-12-8) in multi-location trials: state wise (2010-2012)

State	Year	IET 21974	NC	RC	LC
Odisha	2010	5030	4870	4210	4328
	2011	5488	4403	3903	4537
	2012	4369	4504	3055	4699
	Mean	4962.3	4592.3	3722.7	4521.3
	% increase over control	-	(+) 8.06	(+) 33.30	(+) 9.75
West Bengal	2010	5219	3377	3421	3344
	2011	4815	4155	3829	4028
	2012	6665	5056	5563	5902
	Mean	5701	4196	4271	4424.7
	% increase over control	-	(+) 35.87	(+) 33.48	(+) 28.85
Assam	2012	5815	4755	5071	5091
	% increase over control	-	(+) 22.29	(+) 14.67	(+) 14.22

NC- National control (Dhanrasi); RC- Regional control (Swarna sub 1); LC- Local control

Table 4. Quality characteristics of IET 21974 (CR 2459-12-8)

Quality characteristics	IET 21974 (CR 2459-12-8)	National control (Dhanrasi)	Regional control (Swarna sub 1)
Hulling %	79.65	79.45	80.2
Milling (%)	70.6	68.1	71.2
Head Rice Recovery (%)	63.6	60.25	67.7
Kernel Length (mm)	6.585	5.195	4.65
Kernel Breadth (mm)	2.215	2.445	2.47
Length/Breadth Ratio	2.965	2.315	2.47
Grain type	LB	SB	SB
Grain Chalkiness	A	VOC	NT
Alkali Spreading Value	6	5	5
Amylose Content (%)	23.475	24.265	22.980
Gel Consistency	42.5	34.5	44

LB-long bold; SB-short bold; A: absent; VOC: vary occasionally present; NT: not tested
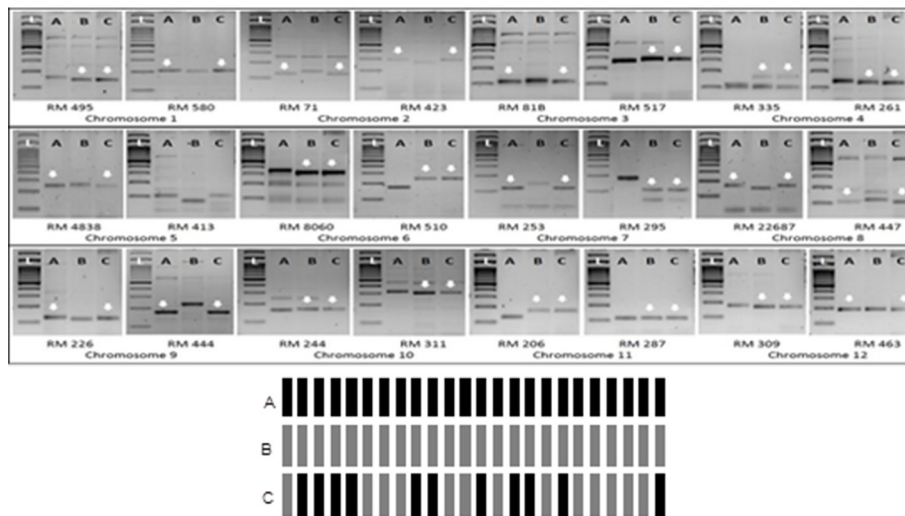

Figure 2. DNA fingerprints of IET21974 (CR 2459-12-8). **i.** DNA fingerprints generated with different markers. L: 100bp ladder; A: Swarna; B: IR64; C: CR 2459-12-8 (Swarna/IR64); Arrow represents allelic similarity of (CR 2459-12-8) with respective parent. **ii.** DNA fingerprint bar graph. A: Swarna, B: IR64, C: CR 2459-12-8. Black bar represents Swarna allele and grey bar represents IR64 allele.

achieving higher production in the rainfed shallow lowlands of India and can also help in enhancing farmers' incomes. Due to its close similarity with the popular cultivar Swarna in terms of husk colour and grain quality traits, this new variety will be extensively adopted by farmers, millers, and consumers of the target area. This newly developed variety has the requisite potential to be an alternative to the popular varieties Swarna, Swarna Sub1, Dhanrasi, and Savitri in the shallow lowland areas of eastern India.

SEED PRODUCTION AND MAINTENANCE

The breeder seed production, and maintenance of the released rice variety CR Dhan 407 was taken up by the seed production unit of the Central Rice Research Institute, Cuttack under the supervision of the breeder involved in its development.

CONCLUSION

The yield stagnation in the shallow lowlands of eastern India can be successfully addressed with the release of CR Dhan 407, a long duration variety with semi-dwarf plant stature, high yield potential, and excellent grain and cooking quality traits. This new variety, with its high yield stability, can bring high economic returns to the farmers of the shallow lowland ecosystem in India through significant increases in rice production in the years to come.

ACKNOWLEDGEMENTS

REFERENCES

Adhya TK, Singh ON, Swain P and Ghosh A (2008) Rice in eastern India: causes for low productivity and available options. **Journal of Rice Research 2**: 1-5.

Araus JL, Slafer GA, Royo C and Serret MD (2008) Breeding for yield potential and stress adaptation in cereals. **Critical Reviews in Plant Science 27**: 377-412.

Collard BCY and Mackill DJ (2008) Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. **Philosophical Transactions of the Royal Society 363**: 557-572.

Cutforth HW, Mcginn SM, Mcphee KE and Miller PR (2007) Adaptation of pulse crops to the changing climate of the Northern Great Plains. **Agronomy Journal 99**: 1684-1699.

Dellaporta SL, Wood J and Hicks JB (1983) A plant DNA mini preparation: version II. **Plant Molecular Biology Reporter 1**: 19-21.

Directorate of Rice Research (2010) Progress report, Varietal improvement. All India Coordinated Rice Improvement Programme (ICAR), DRR, Hyderabad, AP, India 1: 1.31-1.49.

Directorate of Rice Research (2011) Progress report, Varietal improvement. All India Coordinated Rice Improvement Programme (ICAR), DRR, Hyderabad, AP, India 1: 1.61-1.65.

Directorate of Rice Research (2012) Progress report, Varietal improvement. All India Coordinated Rice Improvement Programme (ICAR), DRR, Hyderabad, AP, India 1: 1.32-1.51.

Falconer DS and Mackay TFC (1996) **Introduction to quantitative genetics**. Longman, Essex, 480p.

FAO (2002) Sustainable rice production for food security. In **Proceedings of the 20th session of the international rice commission**. FAO, Bangkok, p. 23-26.

Fehr WR (1987) **Principles of cultivar development**. vol. 1, Theory and technique, Macmillian Publishing Company, New York, p. 95-105.

McCouch SR, Teytelman L, Xu Y, Lobos KB, Clare K, Walton M, Fu B, Maghirang R, Li Z, Xing Y, Zhang Q, Kono I, Yano M, Fjellstrom R, Declerck G, Schneider D, Cartinhour S, Ware D and Stein L (2002) Development and mapping of 2240 new SSR markers for rice (Oryza sativa L.). **DNA Research 9**: 199-207.

Naylor R (2007) The conservation of global crop genetic resources in the face of climate change. In **Summary statement from a bellagio meeting**. Rockefeller Foundation Conference, Bellagio, p. 3-7.

Neto AR, Gallo PB, Junior EUR, Kiihl TAM and Azzini LE (2013) IAC 203 and IAC 204: new upland rice varieties for the State of São Paulo. **Crop Breeding and Applied Biotechnology 13**: 367-370.

Reddy JN, Patnaik SSC, Sarkar RK, Das SR, Singh VN, Dana I, Singh NK, Sharma RN, Ahmed T, Sharma KK, Verulkar S, Collard BCY, Pamplona AM, Singh US, Sarkarung S, Mackill DJ and Ismail AM (2013) Overview of the eastern India rainfed lowland shuttle breeding network (EIRLSBN) SABRAO. **Journal of Breeding and Genetics 45**: 57-66.

Singh BN (2006) Rainfed lowland rice improvement: current status in India and future strategies. **Journal of Rice Research 1**: 104-112.

Singh H, Deshmukh RK, Singh A, Singh AK, Gaikwad K, Sharma TR, Mohapatra T and Singh NK (2010) Highly variable SSR markers suitable for rice genotyping using agarose gels. **Molecular Breeding 25**: 359-364.

Singh VP and Hossain M (2000) Rice area in different ecosystems in eastern India. In Singh VP and Singh RK (Eds) **Best practices and strategies in eastern India**. IRRI, Manila, p. 7-8.

Soares AA, Reis MS, Cornélio VMO, Leite NA, Soares PC, Santos VB, Condé ABT and Reis WP (2013) BRSMG Caçula: very early upland rice cultivar for Minas Gerais. **Crop Breeding and Applied Biotechnology 13**: 208-211.