International Conference on
Agriculture and Allied Sciences:
The Productivity, Food Security and Ecology
ISBN-978-93-85822-71-1

Hybrid Rice Seed Production Technology in India

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Abstract—*Expansion of hybrid rice cultivation area may be an effective and economic way to meet the future rice demands of growing population. The most common, easy and effective means for developing/identifying new hybrids or line is by utilizing cytoplasmic genetic male sterility (CMS) technique in the hybrid breeding programme is fruitful. Hybrid seed production technology is a viable technique and has the potential to give 15-20% more yield then the high yielding variety grown under the similar conditions. The availability of adequate trained human resources is an essential requirement for developing the pure hybrid. Hybrid seed production technology is quite different from the inbred rice breeding. This uses several concept, procedure and skill for the pure seed production.*

Keywords: *CGMS, Hybrid Rice, Technology*

1. INTRODUCTION

Rice is the staple food of half of the world population. In India, rice is cultivated in 44.6 million ha area with 104 million tone production and it shares about 43 % to total food grain production and 46 % to total cereal production. The world population increasing day by day and to meet the demand of the increasing population, the rice production has to be increased. According to the recent estimates, the world food production will have to increase by 70 percent by 2050 to meet the demand of growing population (FAO, 2011). For increase crop productivity, significant efforts in breeding new conventional varieties and hybrids have been made. Since the yield of high yielding varieties (HYVs) of rice is plateauing, it is rather difficult to achieve this target with the present day inbred varieties. Therefore, to sustain the self sufficiency in rice, additional production of 1.5 million tons is needed every year (Guideline for Seed Production of Hybrid Rice, 2010). Commercial exploitation of hybrid vigor is one of the most important applications of genetics in agriculture. It has not only contributed to food security, but has also benefited the environment (Duvick 1999). Rice hybrids were first commercialized in the late 1970s in China. During the past decade, Vietnam, India, the Philippines, Bangladesh and the United States have also begun the commercial production of hybrid rice (Virmani et al. 2007).

The rice hybrids give on an average 10 to 15 q/ha additional yield over the conventional varieties (about 20 % increase). Therefore, to achieve the target production, its introduction and popularization of production technology are feasible and readily adoptable. A genetically pure and good quality seed is not only increases productivity per unit area, but it also produce uniform crops without any admixtures which gives high prices on the market and translates into increased profits (Sindhu and Kumar 2002). Seed production of different class of conventional varieties is much easier with varieties than with rice hybrids because rice is self pollinated crops. The present study was focused on hybrid seed production technology.

2. BACKGROUND

Hybrid rice seed production practices were standardized initially in China during 1976 which paved the way for commercialization of hybrid rice technology. The father of hybrid rice is “Long Ping Yuan” (Singh et al., 2013). The research initiated in 1979 at the International Rice Research Institute (IRRI) for commercialization of hybrid rice technology in tropical countries. But the grain quality of Chinese hybrid was poor as compared to popular high yielding varieties of tropical countries, which recognized that these hybrids were not suitable for tropics. Therefore, IRRI researchers concentrated on developing suitable parental lines specially for the tropics, using the CMS system which had been found to be effective in China. Within a decade, some commercially usable CMS and restorer lines and some elite hybrids were identified and shared with NARS for evaluation and utilization (Virmani et al. 2007).

Taking cue from the success of hybrid rice technology in China, efforts to develop and use hybrid rice technology in India were initiated at the Indian Agricultural Research Institute in early 1970's. However, systematic research work was started in 1989, Indian Council of Agricultural Research (ICAR) launched a special goal oriented and time bound project on ‘Promotion of Research and Development Efforts on Hybrids in Selected Crops’. National Network Project on Rice was initiated at 12 centres with the technical support from the International Rice Research Institute (IRRI), Philippines and Food and Agriculture Organization (FAO), Rome and financial support from United Nations Development Programme (UNDP), Mahyco Research Foundation, World Bank funded National Agricultural

Technology Project (NATP) and IRRI/ADB projects on hybrid rice. With the concerted research work, the country officially released first hybrid in 1994. Till dated, more than 90 hybrids have been released from both public and private sectors (Table1). The generous support from these agencies enabled India to become second country in the world after China to develop and commercialize hybrid rice. The farmer has to purchase seed of hybrid every year and high cost of seed is one of the major constraints in the adoption of the hybrid rice technology. Concerted research carried out for more than a decade resulted in the development of an economically feasible technology for seed production in crops season as well as off season.

3. HYBRID SEED PRODUCTION TECHNOLOGY

Hybrid rice seed is the first filial (F1) generation obtained by crossing two genetically different varieties (parents). Hybrid seed production technology is quite different from the technology for varietal seed production. By utilizing cytoplasmic male sterility, the hybrid seed is produced by using two systems (2-line and 3- line) .The three line system of seed production involving CMS, maintainer and restorer lines are being commonly used for large scale hybrid rice seed production in the world (Ram 2011; Chahal and Gosal 2009; Li and Yuan 2000). The three line consist of

- 'A' line is used as female parent which is cytoplasmic male sterile (CMS)
- 'B' line is maintainer line and isogenic line of 'A' line which is used as pollen parent to maintain male sterility in A line
- 'R' line is fertility restoring line which is called 'restorer'

Using this system for the commercial production of hybrid seeds involves two major steps.

- Multiplication of A line (A x B)
- Multiplication of B and R lines
- Production of hybrid seed (A x R)

'A' line i.e. CMS line is always multiplied by crossing it with its B line. Restorer or 'R line possesses dominant fertility restorer genes, when crossed to a CMS line it restores fertility in the derived hybrid. The hybrid combines the desirable characters from A line and R line. The hybrid exhibits vigour for several quantitative characters including yield and buffering capacity against several biotic and abiotic factor. During evaluation of hybrids, the strains that exhibit heterotic effect for yield are selected. The hybrid seed is purchased afresh every year/ season for commercial crop production. The harvested grains from hybrid crop should not be used for planting the next crop.

4. PARENTAL LINE SEED PRODUCTION

Parental lines get contaminated at different stages of handling and its purification is necessary. Parental lines have to be purified under the direct supervision of the rice breeder. Breeder seed production involves the further multiplication of A, B and R lines using nucleus seed (Singh, 2009; Pandey et al., 2010). The seed chain of nucleus, breeder, foundation and certified seed production should be maintained regularly with highest standard of genetic and physical purity at each of the stages. Purification process essentially involves four steps:

- Growing the source material (Source Nursery)
- Test crossing (Test Cross Nursery)
- Evaluating the test crosses (Identification Nursery)
- Multiplication of the lines (Multiplication Nursery).

Breeder seed production involves the further multiplication of A, B and R lines using nucleus seed. Breeder seed production has to be taken up in a field where no rice crop is grown during previous crop season (Singh, 2009; Viraktamath, 2006). The programme has to be taken up in a field where no rice crop is grown during previous crop season. Recommended isolation distance is 300-500 meters. A row ratio of 2 : 4 and 2 : 6 can be adopted for nucleus and breeder seed production (Singh et al., 2013). The seed material obtained from systematic paired crossing can be used to produce the breeder seed. Meticulous rouging should be at different crop stage for obtaining pure seed. Other practices are similar to those recommended for hybrid seed production. Further multiplication as foundation seed of A, B and R lines can be done in similar fashion.

In CGMS system, those genotypes possessing restorer gene(s) can only be used as male parent. The genotype which shows maintainer reaction can only be converted into CMS lines. Normal frequency of restorers and maintainers in most of germplasm collections does not exceed 30 percent. So in three line system at best only 30% of the germplasm is useful as parental lines and can be utilized in heterosis breeding (Viraktamath, 2010)

5. GUIDELINES FOR SUCCESSFUL HYBRID RICE SEED PRODUCTION

Extensive research has led to the identification of the following guidelines for successful hybrid rice seed production (Yuan 1985, Mao 1988, Virmani 1994, Virmani et al., 2007).

- Selection of seed and pollen parents with synchronized time of anthesis.
- Selection of seed parents with long, exserted stigma, longer duration, and wider angle of floret opening.

ISBN: 978-93-85822-71-1

- Selection of a pollen parent with a high percentage of residual pollen per anther after anther exsertion. High pollen shedding potential is attained by getting 2000 - 3000 spikelets/m2 to bloom per hour during peak flowering period.
- Synchronization of flowering time of the two parents by seeding them at different dates depending on their growth duration or estimated accumulated temperature requirements for initiation of flowering.
- Use of optimum seed parent: pollen parent row ratio such that the ratio of spikelet number per unit area of seed parent and pollen parent is about 3.5:1.
- Use of seed and pollen parents with small and horizontal flag leaves, or cutting long and erect flag leaves.
- Use of gibberellic acid (GA3) to improve panicle exsertion and prolong duration of floret opening and stigma receptivity.
- Planting of seed parent pollen parent rows across the prevailing wind direction and use of supplementary pollination with a rope or stick when wind velocity is below 2.5 m/sec.
- Selection of optimum time of flowering of parential lines in seed production plots.

6. HYBRID RICE SEED PRODUCTION

The production of pure hybrid seed at affordable price in rice- a self-pollinated crop, is a highly skill oriented activity. The success of hybrid seed production depends on various factors such as choice of field, isolation, seeding time, planting pattern and weather conditions during the period of flowering, roguing synchronization in flowering of parental lines, supplementary pollination techniques, proper harvesting, processing, packing and effective seed distribution etc (Virmani et al., 2006; Singh and Prabhu 2009; ICAR, 2009). The hybrid seed should have the purity of about 99 %. Therefore, utmost care has to be taken while producing the hybrid seed. The persons engaged in hybrid seed production should be well trained in various steps involved in hybrid seed production. Following are the requirements for hybrid seed production in rice.

Choice of location and growing season

The areas of seed production should be chosen so as to provide the best possible conditions at flowering and the pollen shedding period. The best condition for seed production are, 24-30^{0}C average temperature, the relative humidity 70-80%, the temperature difference between day and night 8-10^{0}C, preferably 5–7^{0}C and Sufficient sun-shine with moderate wind velocity. There should not be rains continuously for three days during the period of flowering. As a rule, in high temperature with low humidity or in low temperature with high humidity some glume will not open. This lowers the seed yields. The Seed Production areas near forest, rivulets and valleys are better for getting higher seed production.

Selection of field

The land should be fertile, preferably light-textured, with adequate irrigation and a proper drainage system, free from weeds and volunteer plants from the previous paddy crop. To achieve synchronous flowering, a homogenous plot with an even topography is required. The field should be free from serious pests and diseases.

Isolation

A seed production field should be used which is isolated from other rice varieties by distance, time of flowering or some natural or artificial barrier. Space isolation is the most important factor to be considered for the production of quality seed.

- *Space isolation***:** Space isolation of at least 100 m from seed production plots to other rice varieties is normally satisfactory for quality hybrid seed production. For male sterile (A line) multiplication, it is safer to have an isolation distance of up to 200 m for, while for B and R line multiplications in varieties, an isolation distance of 3 to 5 m is sufficient.
- *Time isolation***:** Time isolation of about 30 days is satisfactory, when space isolation is not possible. This means that the flowering stage of the parental lines in the seed production field should be at least 30 days earlier or later than that of other varieties grown within the area to avoid contamination by pollen.
- *Barrier isolation***:** Tall and compact trees or bushes or some tall crops with 30-40 m distance can serve as barrier isolation.

Nursery bed preparation

To obtain healthy and robust seedlings, it is essential to raise the nursery in a well-managed field Puddle the field twice at an interval of 6-7 days to destroy weeds, weed seeds and germinated rice seeds. Construct raised seedbeds (5-10 cm height) of 1m width of any convenient length and provide drainage channels between seedbeds to drain excess water. Apply 5-6 grams of NPK (14:14:14) fertilizer for each square meter of seedbed area and mix it with the soil for increase seedling growth and induce tillering.

Seeding of parental lines in the seedbed

Optimum seed rate should be applied and every seed must be utilized by adopting good nursery management practices. Use 15 kg of ‘A’ line seed and 5 kg of ‘R’ line seed to produce sufficient seedlings to grow one hectare. A sparse well-managed nursery gives healthy seedlings for the main field.

ISBN: 978-93-85822-71-1

Staggered sowing of parental lines for flowering synchrony

Seed set of hybrid primarily depends on flowering synchronization of A line with the R line. The two parental lines should be sown and transplanted at the right times so that their flowering is synchronized. This ensures the continued pollen supply during the flowering period.

For example, the duration of the R line is 10 days more than that of the A line. In such cases, 3 sowings of the R line (i.e. 13, 9 and 5 days ahead of the A line) are carried out.

Transplanting

Timely transplanting (age of 21-25 days) seedlings of A and R lines ensures timely heading and flowering of parental lines. During seedlings pulling out the nursery to transplanting, special care should be taken to avoid mixing of A and R lines seedling

Transplanting of R lines

- Transplant the seedling in paired rows
- Seedling per hill 2-3 and spacing between the plant spacing 15 cm and between the row 30 cm
- Seedlings of different ages transplanted in a sequential order (e.g. I, II, III, then again I, II, III).

Transplanting of A lines

- Transplant the seedling between the paired row of R lines
- Seedling per hill 1-2 and spacing of 15 x 15 cm.

Row ratio and direction

The ratio of A line to R line is generally kept 2:6 or 2:8. For proper growth and production parents should receive good aeration and equal amounts of sunlight. To facilitate out crossing, row direction should be perpendicular to prevailing winds at flowering.

Manure and fertilizer

To achieve the optimum fartilizer use efficiency, recommended dose and proper time of application is important. Application of farmyard manure (FYM) at a rate of least 10 t/ha and a fertilizer dose of 120: 60: 40 kg/ha NPK is recommended in the main field. Half dose of N and full dose of P and K should be applied as basal dose at the time of transplanting. Rest amount of N is applied in two split application as top dressing: first at tillering and second at panicle initiation. This will prolong the pollen supply of the male line and increase tillering capacity. Application of zinc sulphate @ 50 kg/ha, once in three years provides the necessary supplement to overcome the zinc deficiency.

Water management

From panical initiation to grain development, the main field should be irrigated or drained based on the growth stage of the crop (Sindhu and Kumar, 2002):

- Up to the third stage of panicle development: shallow (2-3 cm).
- From the third stage of panicle development to heading: about 5 cm.
- From heading to grain filling: no shortage of water.
- One week before harvesting: water drained out.

Roguing

Rouging is removal of undisirable plant from both the parents. To obtain the physical and genetically pure seed, removal of off type plants should be done at different stages of crop growth. Rouging is done three stages: tillering, panicle initiation and before harvesting. In A line pollen shedders (i.e. maintainer plants) should be removed.

Promotion of panicle exsertion

Panicle exsertion can be promoted by the following techniques

Flag leaf clipping

Long and erect flag leaf may obstruct the pollen dispersal from the R to A line. So the leaf clipping of A and R lines is helpful for uniform distribution of the pollen over A line plants. Flag leaf should be clipped off and the booting stage of plant.

However, it is not advisable to perform leaf clipping in areas where diseases such as bacterial leaf blight, sheath blight and bacterial leaf streak prevail, as they may spread further and reduce seed yield.

GA_3 Application

GA_3 application on parental lines improves the panicle exsertion as well as increases the floret opening, stigma exsrtion, receptivity and pollen parent load. GA_3 to be applied 60-70 gm/ ha on two consecutive days at 5-10% heading. 40% dose on first day and remaining 60% dose on next day should be applied.

Spraying GA_3 also increases plant height by 10-15 cm and so it can also be used to adjust the plant height, in particular of R line in relation to A line.

Supplementary pollination:

In order to enhance the out crossing and hybrid seed production supplementary pollination should be done. Panicle of R line at the time of peak flowering (30-40% of the spikelet are opened) is shaken by rope or sticks so that pollen is shed effectively on A line. This process needs to be done 3-4 times

ISBN: 978-93-85822-71-1

at 30 minute intervals and should be continued for 7-10 days during flowering.

Harvesting

Extreme care is needed during harvesting, threshing and processing of the hybrid rice plots in order to maintaining high purity of seed. Before harvesting rouging should be done on A line to check the pollen shedder and R line plants. After confirmation, firstly harvest all R lines rows. Move the harvested R line plants to a separate threshing floor. Carefully checked for left-over R line panicles before harvesting of A line. A line plants should then be harvested and move on a separate threshing floor. If the harvesting is done by harvest combiner or thresher, extreme care must be taken to clean the machine thoroughly before use to avoid admixture with other varieties.

Threshing

In order to maintain the physical and genetic purity, threshing floor should be free from seed of the previous crop and clean. The A and R lines should be threshed separately.

Seed drying

To maintain the seed longivity, seed should be properly dried. Seeds can be dried either by sun-drying or forced air-drying. After drying, the seed should be properly bagged. The bags should have labels inside and outside, listing all necessary details, such as lot number, name of the parent, location, season, year and date of harvest.

Seed processing

After receiving the seed from seed production area to seed processing plant, weight of every bag should be recorder and lot-wise representative samples drawn. The representative samples are used for testing of germination percentage, moisture percentage, physical purity and seed viability. Based on the test results, the seed from good lots should be processed in the seed conditioning plant.

Seed conditioning should be done one hybrid at a time. For this, the processing plant must be cleaned thoroughly for any left-over seed from an earlier processed variety or hybrid for avoid contamination. In order to maintain good quality standards, the seed is passed through several machines viz., Pre-cleaner (eliminates inert matter), Cleaner (eliminates remaining inert matter i.e. chaffy seed, undersized or small seed), De-stoner (separates mud balls, small stones etc., which are heavier than the seed), Gravity separator: separates light seed for uniform size and clean) and Treator. After that seed is packed with proper label. The label contains information such as: name of hybrid, physical purity percentage (min.); genetic purity percentage (min.); inert matter percentage (max.); other crop seed percentage (max.); weed seed number/kg (max.); germination percentage (min.); and moisture percentage (max.) and date of packaging.

Field and Seed certification standards

Field level

Field inspection number	**Isolation (meter)**		**Off type (%)**		**Objectionable weed/ inseparable other crop plants (%)**		**Objectionable disease (%)**	
Minimum	Minimum		Maximum		Maximum		Maximum	
F & C	F	C	F	C	F	C	F	C
2	3	3	0.050	0.20	0.010	0.050	0.10	0.50
	150	150			Barley, Oat, Triticale, Chickpea		Loose smut	
	Loose smut							

Seed level

Seed of other distinguishing varieties (number/ kg)		**Other crop seed (number/ kg)**		**Total weed seed (number/ kg)**		**Objectionable weeds (number/ kg)**		**Objectionable disease (% by number)**		**Insect damage (%)**	**Pure seed (%)**	**Germination (%)**	**Moisture (%)**	
													Ordinary container	**Vapour proof container**
Maximum		Maximum		Maximum		Maximum		Maximum		Minimum	Minimum	Minimum	Maximum	
F	C	F	C	F	F & C	F	C	F	C	F & C	F & C	F & C	F	C
-	-	10	20	10	20	2	5	None	None	0.5	98	85	12	8
						Convolvulus arvensis, Phalaris minor		Earcockel and Tundu						
								0.05	0.25					
								Karnal bunt						

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Table 1: List of Hybrid Rice Released/Notified in India during 1994-2017

S no.	Rice Hybrids	Year of Release	Duration (Days)	Yield (t/ha)	Developed by	Recommended for
1.	APHR 1	1994	130-135	7.14	APRRI, Maruteru (ANGRAU), Hyderabad	Andhra Pradesh.
2.	APHR 2	1994	120-125	7.52	APRRI, Maruteru (ANGRAU), Hyderabad	Andhra Pradesh.
3.	MGR 1	1994	110-115	6.08	TNAU, Coimbatore	Tamil Nadu.
4.	KRH 1	1994	120-125	6.02	VC Farm, Mandya, UAS, Bangalore	Karnataka.
5.	CNRH 3	1995	125-130	7.49	RRS, Chinsurah (W.B.)	West Bengal.
6.	DRRH 1	1996	125-130	7.30	DRR, Hyderabad	Andhra Pradesh.
7.	KRH 2	1996	130-135	7.40	VC Farm, Mandya, UAS, Bangalore	Bihar, Karnataka, Tamil Nadu, Tripura, Maharashtra, Haryana, Uttarakhand, Orrisa, West Bengal, Pondicherry, Rajasthan.
8.	Pant Sankar Dhan 1	1997	115-120	6.80	GBPUAT&T, Pantnagar	Uttar Pradesh.
9.	PHB 71	1997	130-135	7.86	Pioneer Overseas Corporation, Hyderabad	Haryana, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, Karnataka.
10.	CORH 2	1999	120-125	6.25	TNAU, Coimbatore	Tamil Nadu.
11.	ADTRH 1	1999	115-120	7.10	TNRRI, Aduthurai (TNAU)	Tamil Nadu.
12.	Sahyadri	1998	125-130	6.64	RARS, Karjat (BSKKV)	Maharashtra.
13.	Narendra Sankar Dhan 2	1998	125-130	6.15	NDUAT&T, Faizabad	Uttar Pradesh.
14.	PA 6201	2000	125-130	6.20	Bayer Bio-Science, Hyderabad	Andhra Pradesh, Karnataka, Bihar, Orissa, Madhya Pradesh, Uttar Pradesh, West Bengal, Tamil Nadu, Tripura.
15.	PA 6444	2001	135-140	6.11	Bayer Bio-Science, Hyderabad	Uttar Pradesh, Tripura, Odisha, Andhra Pradesh, Karnataka, Maharashtra, Uttarakhand.
16.	Pusa RH 10	2001	120-125	4.35	IARI, New Delhi	Haryana, Delhi, Western Uttar Pradesh and Uttarakhand.
17.	PRH-122R (Ganga)	2001	130	5.64	Paras Extra Growth Seeds Ltd., Hyderabad	Bihar, Orissa, Punjab, Uttar Pradesh, Uttarakhand, Nagaland, Haryana.
18.	RH 204	2003	120-126	6.89	Parry Monsanto Seeds Ltd., Bangalore	Andhra Pradesh, Karnataka, Tamil Nadu, Haryana, Uttarakhand , Rajasthan.
19	Suruchi 5401	2004	130-135	5.94	Mahyco Ltd., Aurangabad	Haryana, Andhra Pradesh, Karnataka, Gujarat,

ISBN: 978-93-85822-71-1

.						Odisha, Chattisgarh , Maharashtra.
20.	Pant Sankar Dhan 3	2004	125-130	6.12	GBPUAT&T, Pantnagar	Uttarakhand.
21.	Narendra Usar Sankar Dhan 3	2005	130-135	5.15	NDUAT & T, Faizabad	Saline & Alkaline areas of Uttar Pradesh.
22.	DRRH 2	2005	112-116	5.35	DRR, Hyderabad	Haryana, Uttarakhand, West Bengal, Tamil Nadu.
23.	Rajlakshmi (CRHR 5)	2005	130-135	5.84	CRRI, Cuttack	Boro areas of Assam, Orissa.
24.	Ajay (CRHR 7)	2005	130-135	6.07	CRRI, Cuttack	Irrigated areas of Orissa.
25.	Sahyadri 2	2005	115-120	6.50	RARS, Karjat (BSKKV)	Maharashtra.
26.	Sahyadri 3	2005	125-130	7.5	RARS, Karjat (BSKKV)	Maharashtra.
27.	HKRH-1	2006	139	9.41	RARS, Karnal (CCSHAU)	Haryana.
28.	CORH-3	2006	115	-	TNAU, Coimbatore	Tamil Nadu.
29.	JKRH 401	2006	125	6.22	JK Agri. Genetics Ltd. Hyderabad	Bihar, Odisha, West Bengal.
30.	KJTRH 2	2006	N.A.	N.A.	RARS, Karjat (BSKKV)	Maharashtra.
31.	Haryana Shankar Dhan-1 (HKRH-1)	2006	139	9.40	HAU, Haryana RARS, Kaul (CCS, HAU.)	Haryana.
32.	HRI-152 (IET 18815)	2007	120	NA	Bayer Bio-Science, Hyderabad	Punjab & Tamil Nadu.
33.	JRH-4	2007	110-115	7.50	JNKVV, Jabalpur	Madhya Pradesh.
34.	JRH-5	2007	105-108	7.50	JNKVV, Jabalpur	Madhya Pradesh.
35.	Indira Sona	2007	120-125	7.0	IGKKV, Raipur	Chhattisgarh.
36.	PA 6129	2007	115-120	6.58	Bayer Bio-Science, Hyderabad	Punjab, Tamil Nadu, Pondichery.
37.	GK -5003	2008	128	6.04	Ganga Kaveri Seeds Pvt. Ltd., Hyderabad	Andhra Pradesh, Karnataka.
38.	Sahyadri - 4	2008	115-120	6.80	RARS, Karjat (BSKKV)	Haryana, West Bengal, Uttar Pradesh, Maharashtra, Punjab.
39.	JRH- 8	2008	105-110	7.50	JNKVV, Jabalpur	Madhya Pradesh.
40.	DRH - 775	2009	97	7.70	Methelix Life Sciences, Pvt. Ltd. Hyderabad.	Bihar, Chhattisgarh, Jharkhand, Madhya Pradesh, Uttar Pradesh, Uttarakhand, West Bengal.
41.	HRI -157 (IET 19511, 91H97226) (Arize Prima)	2009	130-135	6.50	Bayer Bio-Science, Hyderabad	Chhattisgarh , Gujarat, Bihar, Jharkhand, Odisha, Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka, Madhya Pradesh, Uttar Pradesh, Tripura.
42.	PAC 835 (PAC 80035) (IET 18178)	2009	130	5.60	Advanta India Ltd., Hyderabad	Odisha, Gujarat.
43.	PAC 837 (PAC 80037) (IET 19746)	2009	130	6.30	Advanta India Ltd., Hyderabad	Gujarat, Chhattisgarh, J&K, Andhra Pradesh, Karnataka.
44.	NK - 5251	2009	128	6.65	Syngenta India Ltd., Secundrabad	Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Tamil Nadu.
45.	DRRH- 3 (IET 19543)	2010	131	6.07	DRR, Hyderabad	Andhra Pradesh, Gujarat, Madhya Pradesh, Odisha, Uttar Pradesh Central India.
46.	US - 312	2010	125-130	5.76	Seed Works International, Hyderabad.	Andhra Pradesh, Bihar, Karnataka, Tamil Nadu, Uttar Pradesh, West Bengal.
47.	CRHR-32	2010	125	5.43	CRRI, Cuttack, Odisha	Bihar, Gujarat.
48.	INDAM 200-017 (IET 20419)	2011	120-125	6.60	Indo-American seeds, Hyderabad	Odisha, Chattisgarh, Gujarat Maharashtra, Andhra Pradesh.
49.	27P11 (IET 19766)	2011	115-120	5.67	PHI Seeds (P) Ltd.	Karnataka, Maharashtra.
50.	VNR 2245 (IET 20716) (VNR-204)	2011	90-95	6.83	VNR Seeds Pvt. Ltd., Raipur-492099	Chhattisgarh, Tamil Nadu.
51.	VNR 2245 (IET 20735) (VNR-202)	2011	100-105	5.75	VNR Seeds Pvt. Ltd., Raipur-492099	Uttar Pradesh, Uttarakhand, West Bengal, Maharashtra, Tamil Nadu.
52.	Shyadri-5 (Hybrid)	2011	110-115	NA	RARS, Karjat (BSKKV)	Konkan Region of Maharashtra.

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53.	CO (R) H-4	2011	130-135	7.34	TNAU, Coimbatore	Tamil Nadu.
54.	Hybrid CO 4	2012	130-135	7.34	TNAU, Coimbatore	Tamil Nadu.
55.	US 382 (IET 20727)	2012	125-130	6.70	Seed Works International Pvt. Ltd., Hyderabad-34.	Tripura, Madhya Pradesh, Karnataka.
56.	27P31 (IET 21415)	2012	125-130	8 to 9	PHI Seeds Pvt. Ltd. Hyderabad-82.	Jharkhand, Maharashtra, Karnataka, Tamil Nadu, Uttar Pradesh, Bihar, Chhattisgarh.
57.	27P61 (IET 21447)	2012	132	6.70	PHI Seeds Pvt. Ltd. Hyderabad-82.	Chhattisgarh, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu.
58.	25P25 (IET 21401)	2012	110	6.70	PHI Seeds Pvt. Ltd. Hyderabad-82.	Uttarakhand, Jharkhand, Karnataka.
59.	Arize Tej (HRI 169) (IET 21411)	2012	125	7. 0	Bayer Bio Science Pvt. Ltd, Hyderabad – 81.	Bihar, Chhattisgarh, Gujarat, Andhra Pradesh, Tamil Nadu.
60.	PNPH 24 (IET 21406)	2012	120-130	5.8 to 6.9	Nuziveedu Seeds Limited, Medchal Mandal, Ranga Reddy- 501401 (A.P.)	Bihar, West Bengal, Odisha.
61.	PNPH 924-1 (IET 21255)	2012	125-135	6.2 to 6.7	Nuziveedu Seeds Limited, Medchal Mandal, Ranga Reddy- 501401 (A.P.)	West Bengal, Assam
62.	NK 5251 (IET 19738)	2012	NA	NA	NA	Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat.
63.	VNR 2245 (IET 20716)	2012	120-125	7.0-7.2	VNR Seeds Pvt. Ltd., Raipur 492099	Chhattisgarh, Tamil Nadu.
64.	VNR 2355 Plus (IET 20735)	2012	130-135	5.9-6.0	VNR Seeds Pvt. Ltd., Raipur 492099	Uttar Pradesh, Uttarakhand, West Bengal, Maharastra, Tamil Nadu.
65.	CR Dhan 701	2012	140-145	5.0	NA	Bihar, Gujarat.
66.	JKRH 3333 (IET 20759)	2013 & 2016	135-140	5.98	JK Agri Genetics Ltd, Hyderabad- 16.	West Bengal, Bihar, Chhattisgarh, Gujarat, Andhra Pradesh.
67.	RH- 1531 (Frontline Gold) (IET 21404)	2013	118-125	NA	Devgen Seeds & Crop Technology, Hyderabad	Major Hybrid rice growing regions (Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Karnataka, Maharashtra).
68.	CO 4 (IET 21449) (TNRH 174)	2013	NA	NA	TNAU, Coimbatore	Tamil Nadu, Gujarat, Maharashtra, Uttarakhand, Uttar Pradesh, Bihar, Chhattisgarh, West Bengal.
69.	Arize Dhani	2013	NA	NA	Bayer Bio-Science, Hyderabad	Odisha.
70.	27P52 (IET 21433)	2013	NA	NA	PHI Seeds Pvt. Ltd. Hyderabad-82.	Andhra Pradesh, Chhttisgarh, Gujarat, Odisha, Uttarakhand.
71.	27P63 (IET 21832)	2013	NA	NA	PHI Seeds Pvt. Ltd. Hyderabad-82.	Andhra Pradesh, Chhttisgarh, Karnataka, Uttar Pradesh.
72.	KPH - 199	2013	NA	NA	Kaveri Seed Company Limited, Secunderabad	Andhra Pradesh, Chhttisgarh, Madhya Pradesh.
73.	KPH - 371	2013	NA	NA	Kaveri Seed Company Limited, Secunderabad	Chhattisgarh, Jharkhand, Karnataka, Kerala.
74.	VNR 2375 PLUS (IET 21423) (VNR – 203)	2013	NA	NA	VNR Seeds Pvt. Ltd., Raipur-492099	Bihar, Karnataka, Punjab, Maharashtra, Uttarakhand.
75.	US 305 (IET 21827)	2013	NA	NA	Seed Works International Pvt. Ltd. , Hyderabad-34.	Andhra Pradesh, Tamil Nadu, Maharashtra.
76.	US 314 (IET 21777)	2013	NA	NA	Seed Works International Pvt. Ltd. , Hyderabad-34.	Andhra Pradesh, Bihar, West Bengal, Uttarakhand.
77.	Ankur 7434	2014	NA	NA	Ankur seed Pvt. Ltd.	Chhattisgarh.
78.	PAC 807	2014	NA	NA	Advanta India Ltd. Hydrabad	Chhattisgarh.
79.	PAC 801	2014	NA	NA	Advanta India Ltd. Hydrabad	Uttar Pradesh.
80.	CSR 43 (IET18259)	2014	NA	NA	-	Uttar Pradesh.
81.	JKRH-401	2014	NA	NA	JK Agri Genetics Ltd, Hyderabad- 16.	Uttar Pradesh.
82.	Arize 6444 Gold (IET 22379)	2015	130-135	NA	Bayer Crop Science, Hydrabad	Assam, Chhattisgarh, Odisha, Uttar Pradesh, Bihar Meghalaya, Karnatka, Tamil Nadu.
83.	SAVA 127	2015	115-120	7.5	Savannah seed Pvt Ltd.	Uttar Pradesh.
84.	Arize Tej (HRI 169) (IET 21411)	2015	120	6.5-7.0	Bayer Crop Science, Hydrabad	Bihar, Chhattisgarh, Gujarat, Andhra Pradesh, Tamil Nadu, Jharkhand.

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85.	27P31 (IET 21415)	2015	NA	NA	PHI Seeds Pvt. Ltd. Hyderabad-82.	Jharkhand, Maharashtra, Karnataka, Tamil Nadu, Uttar Pradesh, Bihar, Chhattisgarh, Madhya Pradesh, Odisha.
86.	PAC 801	2015	NA	NA	Advanta India Ltd., Hyderabad	Uttar Pradesh, Jharkhand.
87.	NK 16520	2016	132	6.1	Syngenta India Ltd., Secundrabad	Chhattisgarh, Uttar Pradesh, Bihar, Jharkhand, Odisha, Telangana.
88.	KPH 467 (IET 24142)	2016	126	6.7	Kaveri Seed Company Limited	Chhattisgarh, Madhya Pradesh, Maharashtra.
89.	KPH 272 (IET 24028)	2016	126	4.6	Kaveri Seed Company Limited	Telangana, Karnataka, Tamil Nadu.
90.	JRH- 19	2016	105-110	7.0	JNKVV, Jabalpur	Madhya Pradesh.
91.	37P22 (IET 24122)	2017	126	6.4	PHI Seeds Pvt. Ltd. Hyderabad-82.	Punjab, Haryana.
92.	GK 5022 (IET23445)	2017	123(Aerobic)	4.2	Ganga Kaveri Seeds Pvt. Ltd. , Hyderabad	Bihar, Chhattisgarh.
93.	27P36	2017	NA	NA	PHI Seeds Pvt. Ltd. Hyderabad-82.	Bihar, Madhya Pradesh, Jharkhand.
94.	NPH 8899 (IET 23494)	2017	168(Boro)	5.6	Kaveri Seed Company Limited	Uttar Pradesh, Bihar, Assam.

Source: DRD, Patna

ISBN: 978-93-85822-71-1