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Foreword

Rice has global identity as staple food crop for more than half of the world population. It is one of the premier crop in terms of its caloric contribution to human diet and monetary value of food production in developing world. It has played a great role in alleviating poverty and malnutrition, and reaffirming the need to focus world attention on its role in providing food security eradicating poverty, especially in developing countries. In Asia the yield of HYVs in most of the production system has either been plateaued or declined, most of the cultivable land suitable for rice production has already reached its frontier. Burgeoning population (8.5 billion till 2030) and changing climatic scenario has made it challenging to meet world food demand (about 40% more rice by 2030). In view of above challenges, the adoption of hybrid rice technology which is more remunerative in yield found practically feasible and readily adoptable options to enhance productivity to a substantial height. This technology has been adopted and commercialized in over 40 countries which creates huge business opportunities. Further, this venture creates additional employment and comparatively more income to the rurals, thus, has great scope for improvement of livelihood of the nation.

India has made commendable progress and developed a total of 127 *indica* hybrids for diversified rice ecologies which accounted 8.0% of total rice area in the country. ICAR-National Rice Research Institute has been pioneering the technology and developed three rice hybrids viz. Ajay, Rajalaxmi and CR Dhan 701 for irrigated-shallow lowland ecosystem which are very popular in the states like Odisha, West Bengal, Bihar, Assam, Tripura, Gujarat and commercialized by 19 private seed agencies. Besides, the institute has also invigorated hybrid pools, developed >50 stable CMS lines, maintainers and >100 good restorers.

I congratulate the scientists of the institute for bringing out a research bulletin on hybrid rice technology. This bulletin will help in understanding the process involved in production of rice hybrid seeds and the potential impact it can have in the rice farming. This publication would also serve the reference material for all stakeholders like researchers, producer and policy makers.

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Preface

ICAR-National Rice Research Institute, Cuttack has been pioneering the hybrid rice technology in India quite before the launch of systematic research during 1989. Since inception, institute has made commendable progress and commercialized three popular hybrids namely Ajay (125-130 days), Rajalaxmi (125-130 days; 168 days under *boro*) and CR Dhan 701 (140-145 days) for irrigated and rainfed shallow-lowland ecosystem. Besides, the institute has also developed>50 stable CMS lines (WA, Kalinga-I and *O. perennis* etc. MS cytoplasm), maintainers and >100 good restorers for further HR breeding invigoration. Thehybrid CR Dhan-701 issuitable for irrigated and shallow lowland area of Odisha, Bihar and Gujarat, isfound sustainable under low-light area, therefore, having great scope for the states of eastern part of India where low-light during wet season limits potential expression of hybrids/varieties. The medium duration hybrid, Rajalaxmi is suitable for cultivation under irrigated and shallow-lowland area of Odisha and *boro* area of Assam and Odisha. It has seedling stage cold tolerance, hence suitable for Boro area. Ajay (CRHR7) is a medium duration hybrid bearing long slender (LS) grains is released for irrigated and shallow-lowland area of Odisha.

NRRI's hybrids are very popular among the farmers, covered ~0.174 mha rice area (Ajay in 0.004 ha, Rajalaxmi in 0.11 mha and CR Dhan-701 in 0.06 mha area) during Kh-2019 over five states namely, Odisha, West Bengal, Bihar, Assam, Gujarat and Tripura which added ~ 0.180 mt rice to national food basket. These hybrids are commercialized under public-private partnership mode, licensed to 19 seed agencies which added over Rs. 1.90 crores to the institute's revenue, directly as upfront payment. Moreover, the institute is also working to make this technology more sustainable and amenable to the farmers. We have refined package of practices for hybrid rice seed production at commercial extant. Besides, with the help of state government of Odisha, explored area suitable for hybrid seed production in Odisha and West Bengal.

We acknowledge the contributions of all the authors for bringing out the research bulletin on Hybrid Rice Technology: a profitable venture for improving livelihood of rice farmers in India. We are also grateful to the ICAR (CRP on hybrid technology) and ASEAN group for financial support. We sincerely hope that the bulletin will be useful for all the stakeholders of rice and would assist in further increasing the impacts of hybrid rice technology.

Authors

Contents

1. Introduction

Hybrid technology exploits heterosis in crop plants for economic advantage. This phenomenon has benefited agriculture and fascinated geneticists over 100 years for development of superior cultivar in many crops. It covers large acreage for many crops including rice and has fundamentally affected agricultural practices and the seed industry across the world (Rout et al., 2020). Rice hybrid is the F_1 cross of two genetically distant pureline genotypes, having ability to produce 20-30% more yield than HYVs (Virmani *et al.*, 1981). Hybrid rice (HR) seed production is a profitable venture offer extra income (Rs. 75000-85000/ha net return) and has additional employment opportunity to~20.0 million rurals (requires 100-105 extra man days'/ha area of HR seed production). Therefore, this entity has great scope for improvement of livelihood of the nation (Rout et al. 2020). Given its yield advantage and economic importance, several hybrids in rice have been commercialized in more than 40 countries, which creates a huge seed industry world-wide (Verma et al, 2018). Development of hybrids in rice was first initiated in China during early 1970s. In India, it was started in a systematic way by the Indian Council of Agricultural Research (ICAR) involving twelve network centres in 1989. During the period from 1994 to 2020, India has developed and released a total of 127 rice hybrids (38 from public and 89 from private sector) for different durations (115-150 days) and rice ecosystems (IIRR-Progress Report, Volume-1, 2020, Table-15). At present, hybrid rice area is around 3.5 million hectares, which is about 8.0% of total rice area in India.

2. Hybrid rice system

Hybrid is first filial (F_1) progeny of genetically diverse parents, developed through allogamous mode of reproduction. In rice, natural out-crossing is very low (ranged only 0.3-3.0 %), hence, commercial HR seed production is very cumbersome and expansive task, needs specific parental lines and best agro-management practices (NRRI Technology bulletin-114, Verma et al., 2018). The discovery of male sterile (MS) system makes this technology be realized in rice. The MS is crucial genetic tool for HR breeding which excludes tedious and expansive activity i.e. manual emasculation and facilitates large scale seed production (Verma et al. 2018). Based on availability and their genetic mechanism, two type of MS namely, cytoplasmic male sterile (CMS) and genetic male sterile (GMS) are available for hybrid rice development. The CMS is stable across the ecology and has restorer abundancy, thus, found suitable for hybrid development. Whereas, threshold nature (temperature and photoperiod dependent) of male sterility expression in GMS makes it unstable in tropics, hence, not adopted in India who has vast climatic diversity and dynamics. Based on mechanism of male sterility in rice and parents involved, there are three types of HR seed production systems, namely CMS based three-line system (involves A, B and R lines), GMS based two-line system (involves A and R lines) and apomixis based one-line system is existing (Rout et al., 2020). Amongst, CMS based three-lines system is extensively utilized (seed parent of >90% of world's hybrids) in HR production (Verma et al., 2018). This system involves three parental lines viz., cytoplasmic male sterile line (CMS or 'A'), maintainer ('B') and restorer ('R') lines for developing hybrids. Hybrid seed production using the CMS system involves the following two steps.

- Maintaining 'A' line (by crossing A line with the B line)
- Production of hybrid seed (by crossing A line with the R line)

The 'B' and 'R' lines are multiplied in the same way as inbred varieties. Whereas, A-line multiplication and hybrid seed production are different. The above two systems are schematically presented in the figures 1 & 2.

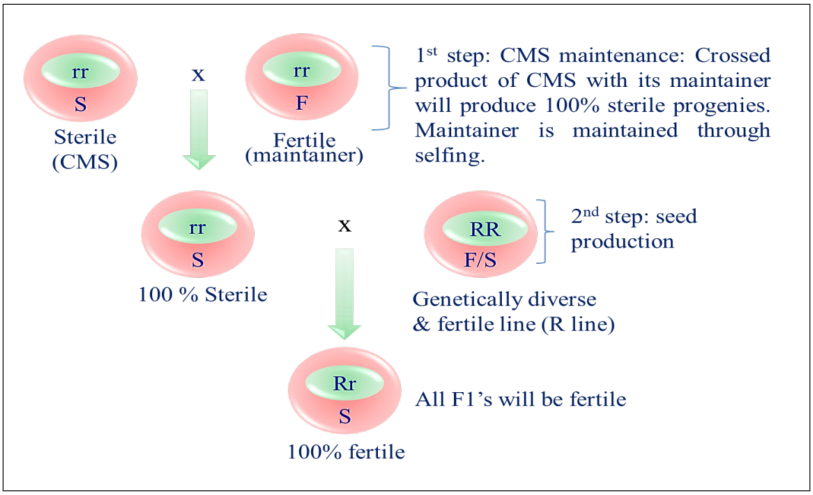


Figure 1: Schematic presentation of hybrid rice seed production technology

Figure 2: Field view of hybrid seed production

3. Hybrid rice progress in India

Since inception of HR in project mode during 1989, so, far, the country has released 127 (*indica/indica*) heterotic (15-20% yield superiority over inbreds) rice hybrids for diverse agro-climatic conditions (115-150 days). Besides, developed >100 stable CMS and respective maintainers indigenously under diversified genetic and cytoplasmic background. The promising CMS lines like CRMS 8A, CRMS 31A, CRMS 32A, CRMS 53A, CRMS 54A, CRMS 56A, PMS10A, DR8A, PMS 17A, APMS 6A, PUSA 5A, RTN 12A, PUSA6A, etc. are being utilized in HR breeding programs in India and abroad. Remarkably, a medium duration CMS, CRMS 32A having seedling stage cold tolerant is developed indigenously under Kalinga-I cytoplasm is found suitable for breeding hybrids for *boro* ecology. The hybrids released in India are adaptable to tropical and subtropical ecologies, having unambiguous specificity towards habitat, sustainability and consumer preferences (Table 1). Therefore, to harness maximum potential and benefit, only suitable hybrids should be adopted under recommended condition/area (Table 2).

Table1. Suitability of rice hybrids against biotic and abiotic stresses

S. No.	Stress	Hybrid
1	Rain-fed upland	DRRH-2, Pant Sankar Dhan-1, Pant Sankar Dhan-3, KJTRH-4
2	Saline soil	DRRH-28, Pant Sankar Dhan-3, KRH-2, HRI-148, JRH-8, PHB-71, Rajalaxmi
3	Alkaline soil	Suruchi, PHB-71, JKRH-2000, CRHR-5, DRRH-2, DRRH-44, Rajalaxmi
4	*Boro* season	Rajalaxmi, CRHR-4, CRHR-32, NPH 924-1, PA 6444, Sahyadri, KRH 2, RRX113, RRX336
5	BB resistant	BS 6444G, Arize Prima, Rajalaxmi, Ajay, CR Dhan 701, PRH 10
6	BPH tolerant	Arize AZ 8433 DT

Hybrids like 25P25, 27P31, CRHR 105, CRHR 106, CRHR 150 are heat tolerant in nature, hence, suitable for yield enhancement under heat stress. The hybrids, JKRH 401, US 382, US 312, Indam 200-17, DRRH3, are highly N use efficient, thus, are appropriate for the soil which is poor for N content. Moreover, hybrids, RH 1531, Arize Tej, CRHR 105, CRHR 106 and PNPH 24 are mid-early maturing varieties suitable for water scarcity situation. The coastal and shallow-lowland areas which is sharing ~ 32% of the total rice area but remains low productive, can be benefited by adopting late maturity HR varieties, CRHR 32, Arize Dhani, CRHR 34, CRHR 102, CRHR 103 and Sahyadri 5 (Table 3).

Table 2: State-wise suitable rice hybrids in India

State	Identified hybrids
U.P.	NDR-2 NDRH-3, KRH-2, PRH-10, PSD3, PSD 1, PHB 71, PA 6444, PRH-122, NUSD-3, Sahyadri-4, ARIZE PRIMA, PAC 835, PACH 837, US 312, 27P61, RH 1531 & 27P63
Bihar	KRH-2, PRH-10, JRH-5,, CRHR-32, US-314, VNR 2375 PLUS, HRI 169, JKRH 3333, PNPH-24, US-312, PAC 835, PACH 837, JKRH-401
Jharkhand	KRH-2, PRH-10, JRH-5,, CRHR-32, US-314, VNR 2375 PLUS, HRI 169, JKRH 3333, PNPH-24, US-312, PAC 835, PACH 837, JKRH-401, BS 6444G
Chhattisgarh	Indira Sona. KRH-2, JRH-4 JRH-5 and JRH-8, PRH-10, PAC 807 , ANKUR 7434, KPH-371, KPH-199, 27P63
Punjab	KRH-2, PRH-10,
Gujrat	KRH-2, PRH-10, CRHR-32
Odisha	KRH-2, Ajay, Rajalaxmi, CR Dhan 701, Sahyadri-1, Sahyadri-2, Sahyadri-3,PAC835, JKRH-2000,PA6444, CRHR 32, Arize Dhani, PAC 837, 27P31, NK 16520, MEPH 126, 28P09, 28P67, 28P41, BIO 799, CNRH 102, 27P36
M.P.	JRH-4. JRH-5,JRH-8, Indira Sona.PRH-10, KRH-2
Maharashtra	Sahyadri-1,Sahyadri-2, Sahyadri-3, KRH-2, PRH-10, DRRH-2
AP	DRRH 1,2,KRH 2, Sahyadri 1, CNRH 3, US 305 , RH 1531, 27P61
Assam	KRH 2, Ajay, Rajalaxmi,PA6444
Kerala	TNRH 1, KRH 2
Karnataka	KRH 2, Sahyadri 1, 2, 3
TN	TNRH 1, KRH 2
WB	KRH-2, Ajay, Rajalaxmi, Sahyadri-1, Sahyadri-2, Sahyadri-3,

Table 3. Hybrids suitable for specific condition/quality

Aerobic condition	PSD 3, Rajalaxmi, PSD 1, Ajay, KRH 2, PRH 122, ADTRH 1, DRRH 44, JKRH 3333, HRI 126,
Early duration	27P31, CRHR 105, 25P25, CRHR 106, (heat tolerant), Indam 200-17, US 382, US 312`, JKRH 401, DRRH3, high N use efficient; RH 1531 and PNPH 24 , Arize Tej drought tolerant; KJTRH-4 and DRRH2 (upland)
Long duration	CRHR 32, Sahyadri 5, CRHR 34, CRHR 100
SRI	KRH 4, TNRH CO-4
Idly making	VNR 2355+
MS grains	27P63, CRHR 32, DRRH 3, 25P25, Suruchi
Aromatic	PRH 10, PRH 122, Indam 200-012 (minor aroma)

4. Hybrid rice research at NRRI

The ICAR-NRRI is pioneer institute started breeding HR well before during 1979, has acquired requisite genetic materials (CMS viz. V 20A, Yar Ai Zhao A, Wu10A, MS 577A, *Pankhari*203A, V 41A, Er-Jiu nanA; respective B-lines, and 9 other maintainers; and 13 good restorers) from the International Rice Research Institute, Philippines (NRRI annual report 1981-82).Subsequently, under target oriented inter-disciplinary approach, institute has made commendable progress, could develop three popular hybrids namely Ajay (125-130 days), Rajalaxmi (125-130 days; 168 days under *boro*) and CR Dhan 701 (140-145 days) for irrigated and rainfed shallow-lowland ecosystem. Besides, the institute has also developed 57 stable CMS lines (WA, Kalinga-I and *O. perennis* etc. MS cytoplasm), respective maintainers and >100 good restorers for further HR breeding invigoration. Among the CMS, Annada A (WA), Pusa 33A (WA), Sarasa A, Manipuri A (WA), Kiran A (WA), Moti A (WA), Deepa A (WA), Krishna A *(O. perennis),* Krishna A (Kalinga I), Padmini A, Mirai (Kalinga I), PS92A and Sahbhagidhan A etc. (Table 4). are more prominent and extensively utilized for hybrid development. The CMS, CRMS31A (WA) and CRMS32A (Kalinga-I) are substantially utilized in varietal development in India. The medium late duration CMS, CRMS24A, CRMS40A and CRMS 56A (>45% outcrossing) are suitable for development of late duration hybrids; and short duration CMS, CRMS8A, CRMS51A, CRMS52A, CRMS53A, CRMS 54A (Figure 2) are useful for hybridization of rainfed-upland area/ ecosystem.

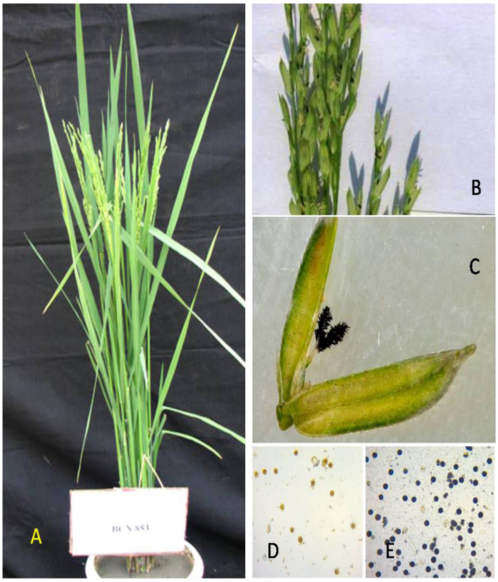


Figure 2: a-CRMS54A, a medium duration, good combiner WA-CMS under genetic background of CR 440 (CRMS 32B/DR8B), b&c-purple color dual stigma exsertion, c-wide angle of opening and > 30% out-crossing.

Table 4: List of CMS developed at NRRI, Cuttack

CMS Source	CMS lines developed
WA-CMS	CRMS5A, 6A, 7A, 8A, 10A, 11A, 13A, 15A, 16A, 17A, 18A, 19A, 23A, 24A, 25A, 26A, 27A, 28A, 29A, 30A, 31A, and 34A, 51A, 53A, 55A, 57A
O. perennis	CRMS22A, 35A, 36A
V20B	CRMS20A
Kalinga I	CRMS21A, 32A, 33A, 52A, 55A, 56A
Lalruma	CRMS37A
Miz.21	CRMS 44A, CRMS45A

The hybrid, CR Dhan-701 (IET20852) is late in duration (145 days) recommended for cultivation under irrigated and shallow lowland area of Bihar, Gujarat and Odisha. This is a medium slender (MS) grain hybrid with > 60% HRR and 7.5 t/ha yield ability, sustainable under low-light area, therefore, having great scope for the states of eastern part of India where low-light during wet season limits potential expression of hybrids/varieties (Figure 3). The Rajalaxmi (125-130 days) is medium duration hybrid, developed utilizing CMS, CRMS32A and released through SVRC-2006/CVRC-2010 for cultivation under irrigated and shallow-lowland area of Odisha and *boro* area of Assam and Odisha. It has seedling stage cold tolerance, hence suitable for Boro area. Ajay (CRHR-7) is a medium duration hybrid bearing long slender (LS) grains is released for irrigated and shallow-lowland area of Odisha. Given to their remuneration ability and popularity in eastern states, altogether 19 private seed agencies have taken license for commercialization (Table-14).

Figure 3: Field view of CR Dhan 701 (CRHR 32)

The institute has made commendable progress towards making HR technology more sustainable and amenable to the farmers. The hybrids, Ajay, Rajalaxmi and CR Dhan-701 have been improved for resistance against bacterial blight which is most devastating disease of rice (Das et al. 2016). The sustainability of hybrids, Ajay and Rajalaxmi is also enhanced against submergence and salinity stress. We could improve outcrossing in seed parents, CRMS31A/B and CRMS32A/B through genomics approach. Further, to address the IP issues and ensure pure seed availability of parents/hybrids, genotype specific signature markers could distinguish 32 hybrids are developed (Verma et al. 2018).

5. Hybrid rice in Odisha

In Odisha, rice with 4.17 mha area and 8.30 mt of total production, is directly linked with the state economy (Agricultural Statistics at a glance 2015). The majority of rice area in the state comes under rainfed situation (irrigated-27.4%; rain-fed upland-19.1%; medium land-12.4%; shallow lowland-22.5%; semi-deep- 7.9%; and deep water-3.4%) of that ~

50% land (irrigated and shallow lowland) is suitable HR cultivation. The state is also most suitable for hybrid rice seed production as it experiences favorable range of important climatic parameters like temperature, rainfall, relative humidity (36% to 98%) and the average bright sunshine hours (3.7 hrs/day in the month of July-August to 8.8 hrs/day during the months of March to May). State has adopted hybrid rice cultivation for past several years; more than 15 suitable rice hybrids were released for the states (Table-5). To further scale up rice production, Odisha Gov. has approved a plan for hybrid rice seed production with an incentive of Rs. 20000/ha area (Sadananda Mohapatra, Bhubaneswar. October 7, 2014). It's every year mandatory fresh seed requirement ensures 100% seed replacement rate (SRR) which is found to be substantial for enhancement productivity in rice. The state government has plan to enhance variety replacement ratio (VRR)of rice by replacing them with hybrid (ensures 100% seed replacement with additional >Rs. 20000.0 net return (T.K. Samant, 2014) and improved varieties (Draft Agricultural Policy of Odisha 2019, pp-13).

Table-5: hybrid varieties recommended for Odisha

Name of hybrid	Year of release	Duration (days)	Avg.Yield (t/ha)	Grain type	No. of MoU signed
Rajalaxmi	2006, 2010	125-135	7.0-7.5 t/ha	LS	11
Ajay	2006	125-135	7.0-7.5 t/ha	LS	06
CRHR 32	2014	145-150	7.0-7.5 t/ha	MS	09
PAC-835	2009	130	7.0-7.5 t/ha	MS	Advanta India Ltd.
PAC-837	2009	130	7.0-7.5 t/ha	LB	Advanta India Ltd.
Arize Dhani	2013	145-150	6.0-6.5 t/ha	MB	Parent institute
27P31	2015	130	6.5-7.0 t/ha	LS	-do-
BS 6444G	2015	135-140	6.5-7.0 t/ha	MB	-do-
NK 16520	2016	130	7.0-7.5 t/ha	LS	-do-
MEPH 126	2017	135-140	7.0-7.5 t/ha	LS	-do-
28P09	2017	140	6.5-7.0 t/ha	LS	-do-
28P67	2017	135	7.0-7.5 t/ha	LS	-do-
28P41	2017	130	6.5-7.0 t/ha	LS	-do-
BIO 799	2017	130	7.0-7.5 t/ha	LS	-do-
CNRH 102	2017	130	7.0-7.5 t/ha	LS	-do-
27P36	2018	130	6.0-6.5 t/ha	MS	-do-

Hybrid rice seed production which is earlier centered to few districts of Andhra Pradesh now also extended to Odisha and West Bengal. More than 10 major private seed agencies (Bayer-2000 acres, US Agri-1000 acres, Dhanya-600 acres, VNR-300 acres, Syngenta-1000 acres, Pioneer-700 acres, PAN-100 acres, Sansar Agropol-300 acres, Sai Sraddha-60 acres, Balaji Seeds-200 acres, Mali Seeds-60 acres, Anima Seeds-120 acres etc.) are involved in large scale seed production and many more are finding place in Odisha. During *Kharif*, 2016, total 4510 tons of 22 hybrids was produced and sold which was covered 0.30 mha area in the states. State government has launched several plans to upscale hybrid rice seed production to boost productivity and farmers' economic status in the state. Union government used to provide chance through central scheme (RKVY) for seed companies to produce hybrid seed in Odisha and the state government would also provide subsidies ("Incentives of Rs 20,000 per hectare) to farmers involved in the venture.

6. Impact of NRRI's hybrids

The institute has commercialized three hybrids, Ajay, Rajalaxmi and CR Dhan 701 which are very popular among farmers. Based on quantity of F_1seed sold during 2019, these hybrids are estimated to covered ~0.174 mha rice area (Ajay in 0.004 ha, Rajalaxmi in 0.11 mha and CR Dhan 701 in 0.06 mha area) during Kh-2019 over five states namely, Odisha, West Bengal, Bihar, Assam, Gujarat and Tripura which added ~ 0.180 mt rice to national food basket. These hybrids are commercialized under public-private partnership mode, licensed to 19 seed agencies (Table14). During 2009-2021, total 38 memorandum of understandings (MoUs) were signed which added over Rs. 1.9 crores to the institute's revenue, directly as upfront payment.

7. Hybrid rice seed system

Hybrid rice is best available option to enhance rice productivity in favorable ecosystem (~50% of total rice acreage is suitable). In India, this venture is dominated by private seed sector where > 300 private seed agencies are involved, amongst ~30 are leading, producing seeds on more than 1000 ha area. The public sector supports this endeavor through technology generation and optimization. Among the public sector agencies, State Seed Corporations of Maharashtra, Karnataka and Uttar Pradesh and National Seed Corporation are taking up hybrid rice seed production on a small scale. Private seed agencies follow centralized contract farming model for hybrid seed production and it works on the agreement between the farmers and private seed company. Contracting companies provide financial support (an incentive of Rs. 45000.0 for field management) to the producer farmers, and buy back the F_1 produce at the rate of Rs. 80-90/kg, which are marketed to the growers at the rate of Rs. 350-450/kg (NRRI Technology bulletin-114). Hybrid seed market follows 'distributor/dealer/retailer' network to make the seed available to the farmers. Moreover, because hybridization provides innovators with the ability to recoup their investments in research, hybrid rice represents a technology platform on which both private-sector scientists and entrepreneurs can make profitable and socially beneficial investments. Public-private partnerships for hybrid seed production have been fructified in India by the signing of memorandums of understanding (MOU) by some companies with few public sector research institutes.

8. Hybrid rice business scope

Hybrid rice with remunerative grain yield (1.0-1.5 t/ha more yield, 15000-22000 additional income) and 100% seed replacement rate (SRR), has great scope for hybridizing country's favorable rice area (50% area, ~20 mha) and increase rice production ~20.0 mt. HR seed production is more profitable (Rs. 80000-85000 /ha net income, 70% more than production cost) than of HYVs (~Rs. 15000.0/ha, 18% more than production cost), so, country has great business scope (Rs.10500.0 crores, annually) as we require total 3.0 lakh tones of seeds for covering 20.0 mha favorable area (NRRI Technology bulletin-114, 2015). Per hectare hybrid rice seed production requires 100-105 additional man days, hence, this venture is able to create additional employment opportunity for over 20 million locales which might be decisive in improving the livelihood of the rice farming community (Table 6).

Table 6: agribusiness opportunity in hybrid rice seed industry

Area coverage of hybrid during-2020	3 m.ha.
Seed requirement for 3m.ha @ 15.0 kg/ha	45000 tons
Cost of seed: (@ Rs. 3.5 lakhs/ton)	Rs.1575.0crores
Scope for hybrid rice in the country	20m.ha
Seed requirement for 20m.ha	3 .0 lakh tons
Cost of seed : (@ Rs.3.5 lakhs/ton)	Rs.10500.0 crores
Area required for seed production for 3m.ha. (@ 1.5t/ha producibility):	30,000ha.
Employment opportunity: 100-105 additional man days	2.0 crores man days

*Extra employment opportunity: seed industry, processing, marketing and distribution

9. Hybrid rice seed production

Success of HR technology depends upon efficient and economically viable large scale seed production. It is reported that the yield of F_1 hybrids and parental lines will decrease by 0.8% (100 kg/ha) and 45%, respectively, when the seed purity decreases by 1% (Mao, 1998) and inappropriate management (FAO-2001) in seed production field. So it is very important to establish a system of seed production to ensure the seed purity of the parental lines and the hybrid. Rice is a self-pollinated crop, where the extent of natural out-crossing ranges from 0.3 to 3.0% (Kumar, 1996). The success of hybrid seed production however demands higher out-crossing rate to obtain high seed yield. Therefore, hybrid rice seed production requires specialized techniques, which need to be thoroughly understood before embarking upon this venture. Various factors that affect hybrid seed production include choice of field, isolation, seeding time, planting pattern, weather conditions during flowering, roguing, synchronization in flowering of the parental lines, supplementary pollination and post-harvest operations. The present effort aims at providing critical information for successful hybrid rice seed production, which will of immense use for the agencies/ individuals involved in such a venture (NRRI technology bulletin-114, 2015).

9.1. Choice of location:

As it is well known that rice hybrid seed production is a cumbersome practice, a viable seed production requires specific location having fertile field with proper irrigation and drainage system, sufficient sunshine during flowering, and no serious disease and insect problems. Therefore, while choosing location for hybrid seed production above said requirements should be considered.

9.2. Favorable climatic conditions:

Climatic conditions have profound influence on the seed yield. Detailed information on the weather data of a given locality is necessary for fixing the seeding dates. Seeding of the parental lines should be planned in such a way that the flowering in both parents coincides with the most favorable climatic conditions, which are as follows:

i. Overall daily mean temperature of 24^0– 30^o C
ii. Relative humidity ranging from 70 – 80 %
iii. The differences between day and night temperatures should not be more than 8^0–10^oC (5^0-7 ^{0}C is optimum).
iv. Sufficient sunshine with moderate wind velocity (2-3m/sec).
v. There should not be rains continuously for three days during the period of flowering.
vi. Yield will be adversely affected if overall daily mean temperature during flowering is below 20^oC and above 35^oC.

9.3. Isolation:

Rice pollen grains are very tiny and light in weight and thus can travel very far with low speed of wind. In order to ensure the purity of hybrid seed and avoid pollination by unwanted rice varieties, the seed production plots should be strictly isolated. There are several methods available, any of which can be practiced to avoid the unwanted pollination. These are as follows.

9.3.1. Spatial isolation: Unwanted varietal contamination in hybrid seed production can be prevented by maintaining atleast 100-meter distance between hybrid seed production plots and plots of other varieties, and500-meter distance for CMS line maintenance.

9.3.2. Time isolation: Wherever it is difficult to have space isolation, a time isolation of over 21 days would also be effective. It means that the heading stage of the parental lines in hybrid seed production plot should be 21 days earlier or later than that of other varieties grown in the vicinity.

9.3.3. Barrier isolation: In some places, the natural topographic features such as mountains, rivers, forests etc. can serve as the most effective barrier. A crop barrier with maize, sugarcane and *Sesbania* covering a distance of 30 m would also serve the purpose of isolation. Artificial barrier with polythene sheets and seed nets of about 3 m height can also be used in case of small scale seed production. However, the most ideal locations are the areas covered with hillocks and mountains, which act as natural barriers.

Figure 4: Space isolation

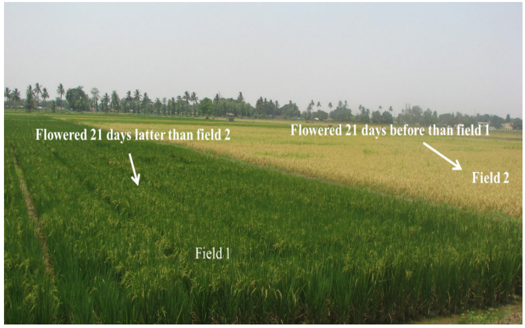


Figure 5: Time isolation

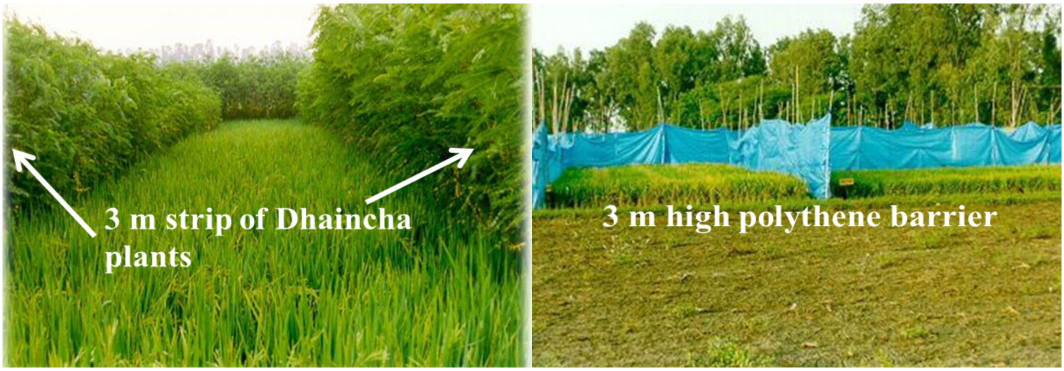


Figure 6: Physical barrier

9.4. Nursery management and seed rate

Around 600-800m^2 nursery area is required for transplanting one-hectare land. Before seeding, puddle the seedbed field twice (at an interval of 6-7 days) and keep the water continuously for 4-5 days. After that drain the excess water and puddle (2-3 times) in wet condition to destroy weeds, weed seeds and germinated rice seeds.

i. Prepare raised seedbeds (5-10 cm height) of 1m width of any convenient length.

ii. Provide drainage channels (30 cm) in between seedbeds to drain excess water.

iii. Apply recommended fertilizer and manures (500: 500: 500g./100m^{2}N, P, K and 50 kg/100m^{2}FYM) to the nursery beds. Double the phosphorus dose where low temperature retards seedling growth and apply zinc shulphate @ 3-4 kg/1000m^2 in zinc deficient area.

iv. Sow pre-germinated seed uniformly on the seedbed (@ of 1-2kg seed/20m^2)

v. Use 15 kg of `A' line seed and 5 kg of `R' line seed to produce sufficient seedlings to grow in one hectare each.

vi. Manage the seedbed properly for getting healthy and vigorous seedlings for transplanting.

vii. To avoid the fungal diseases in nursery, seed treatment with Carbendazim 50% WP @ 4g/kg seed should be ensured.

viii. For proper seedling growth, maintain the optimum moisture in nursery and apply urea @ 600-800g/100m^2 after 15 days of sowing.

ix. Avoid excess nitrogen application in nursery; it affects the flowering synchronization in parental lines.

Figure 6: Nursery preparation and sowing of germinated seeds

9.5. Seeding and transplanting sequence

The seeding sequence of seed parent and pollen parent in the hybrid rice seed production plot depends on the growth duration of seed parent (A line) and pollen parent (R line). Therefore, to attain the complete synchronization in parental lines and long duration availability of pollens, male parent (B/R line) must be sown in three staggered date (at 3-4 days interval) and transplanted as per patterns given in table.

9.5.1. In case seed parent (A line) has 10 days longer growth duration than pollen parent (R line): In this situation sowing of A line is to be completed first. Three staggered sowing of R line is to be started on 6th day of sowing of CMS line and would be completed with 4 days interval (as given in Table 7). Transplant 25day old seedlings of the `A' line 10 days earlier than `R' line. All R line to be transplanted 10 days later of CMS line planting the age of 2nd sown R line would be 25 days older (Figure 8; scheme 2).

Table – 7: Seeding sequence and seedling age for transplanting

S. No.	Seed/pollen parent	Seeding sequence	Seedling age for transplanting (days)
1	A line	0 day	25
2	First R line	6th day	29
3	Second R line	10th day	25
4	Third R line	14th day	21

9.5.2. In case seed parent (A line) has 10 days shorter growth duration than pollen parent (R line): In such case seeding of R line has to be done in three staggered date with 4 days interval (as given in Table: 8). Seeding of CMS line needs to be done on 14th day of first seeding of R line. The seedlings of the R line are to be transplanted when the age of the 2nd date sown R line reaches 25 days. All three staggered sown R lines are to be transplanted simultaneously. Later, 25 days old seedlings of the A line are to be transplanted 10 days later than the second R line seedlings.

Table –8: Seeding sequence and seedling age for transplanting

S. No.	Seed/pollen parent	Seeding sequence	Seedling age for transplanting (days)
1	First R line	0 day	29
2	Second R line	4th day	25
3	Third R line	8th day	21
4	A line	14th day	25

9.5.3. In case seed parent (A line) has same growth duration as pollen parent (R line): In such case, first seeding of R line is to be done 4 days before seeding of CMS line. CMS line and second staggered seeding of R line need to be done simultaneously on 4th day of first seeding of R line. Last seeding of R line to be done on 8th day of first sowing. Transplanting of both A and R lines to be done simultaneously. First A line planting is to be completed with 25 day old seedlings followed by R line with the seedling age of 29 days (1st sown R line), 25 days (2nd sown R line) and 21days (3rd sown R line) old (Table 9, Figure 8; scheme 3).

Table –9: Seeding sequence and seedling age for transplanting

S. No.	Seed/pollen parent	Seeding sequence	Seedling age for transplanting (days)
1	First R line	0 day	29
2	Second R line and A line	4th day	25
3	Third R line	8th day	21

9.5.4. Corrective measures for flowering synchronization in production plot : Flowering synchronization between parental lines of a hybrid is a major seed productivity determinant. Even after all the required management practices are followed, synchronization of flowering between parental lines remains incomplete. Generally, it occurs due to either microclimatic changes in the field or in the environment, which cause advancement or delay (4-6 days in either direction) in flowering. For instance, excess application of nitrogen and less water availability cause delay, whereas extra dose of phosphorus and flooding causes advancement in flowering. This type of mismatch can be overcome through some cultural as well as chemical management practices.

Advancement in flowering can be achieved by spraying 1% solution of Phosphoric acid before 3rd stage of panicle development (up to 7-9th days of panicle initiation) or application of single super phosphate @ 50-60 kg/ha in male row and 100 kg/ha in female row. This causes 4-5 days advancement in flowering. Delaying in the flowering can also be achieved by spraying 2% solution of urea or 50-60 kg/ha nitrogen in male and 75-100 kg/ha in female rows before 3rd stage of panicle development. This causes 4-5 days delay in flowering. Some other corrective measures as given in Table-10, can also be successfully applied in flowering adjustment of parental lines in seed production plots. Dual corrective measures of opposite effect on male and female parents will be more effective in getting good response.

Table 10: Corrective measures for adjustment in flowering

S. No.	Name	Chemical Quantity		Stage of Application	Adjustment possible (Days)
		Male	Female		
Approaches for delaying flowering					
1	Urea broadcasting Urea spray	50-60Kg/ha 1-2%	75-100Kg/ha 1-2%	Before III Stage Before III Stage	4-5 2-3
2	Paclobutrazol spray	1.0Kg/ha	1.5 Kg/ha	Before III Stage	6-8
3	Draining out water	Effective	Not effective	I-V stage	2-3
4	Leaf clipping	Effective	Effective	VII-VIII Stage	2-3
5	Removing panicles	1-3 times	1-3 times	At heading	5-6
6	Delayed GA3 application	Effective	Effective	At 40-50% flowering	1-2
7	Walking on root zone	Effective	Effective	After PI	2-3
Approaches for advancing flowering					
1	SSP broadcasting	50-60Kg/ha	100Kg/ha	Before III Stage	4-5
2	MOP broadcasting	10-20Kg/ha	30-40 Kg/ha	Before III Stage	4-5
3	Flooding	Effective	Not effective	Before III Stage	2-3
4	GA3 application	10-15 g/ha	10-15 g/ha	At heading	2-3
5	Boric Acid	100 g/ha	150 g/ha	Before III Stage	1-3

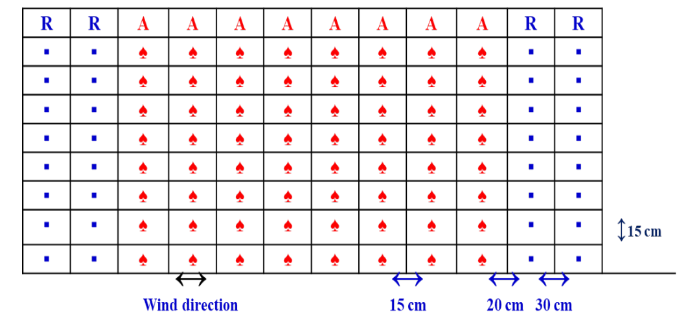
9.6. Transplanting:

To ensure good plant growth, complete flowering synchronization between parental lines and higher seed producibility, it is necessary to transplant the parental lines at proper seedling age. Seedlings of both, A and R lines are to be transplanted when they attain the age of 21-25 days. Transplanting of older seedling (one-day old seedling may cause half day delay in flowering and vice-versa) delays flowering and transplanting of younger seedling advances flowering. If the transplanting of seedlings of 'A' line is delayed, then delay transplanting of the 'R' line by the same number of days is necessary. One or two seedlings per hill of the 'A' line and 3-4 seedlings per hill of B/R (male lines) are to be transplanted. For uniform distribution of pollen parent in the seed production plot, staggered sown seedlings of R line should be properly mixed before transplanting (Figure: 7). Every transplanted hill of B/R line should contain seedling of each staggered, so, planting atleast 3 seedlings/ hill has to be ensured.

Figure 7: Mixing of staggered sown B/R line seedlings

9.6.1. Transplanting in a specific row ratio and row direction: In hybrid rice seed production, the seed parent and pollen parent are planted in a certain row ratio at certain spacing (Figure 8; scheme1). The row ratio and spacing of pollen parent and seed parent have a distinct effect on the hybrid seed yields. The row ratio or row proportion refers to the number of rows of the male parent (R line) to that of the female parent (A line) in a seed production plot. Suppose if we plant 2 rows of 'R' line followed by 8 rows of 'A', the row ratio can be taken as 2:8. In hybrid rice seed production plot,2:8 row ratio is reasonable. However, the row ratio may vary from region to region, depending on weather, management and parental lines. R and A lines can be planted in several row ratios of 2:6-14for hybrid seed production but for maintaining the CMS line, it should not exceed 2:6-8. To encourage out-crossing, the rows of male and female in the seed production plot should be perpendicular to the prevailing wind direction expected at flowering time of the parents.

Scheme 1: Row Ratio, Row Direction and Planting Pattern for Hybrid Rice Seed Production (Male : Female ratio = 2 : 8-14)



9.6.2. Factors influencing row ratio: The ratio of pollen parent (R line) to seed parent (A line) is determined by the characteristics of the parental lines.

- Height of the pollinator
- Growth and vigor of the pollinator
- Size of the panicles and amount of residual pollen
- Duration and angle of floret opening in CMS lines
- Stigma exsertion of CMS lines

9.6.3. Transplanting of the R line

- Transplant the seedlings of R line in paired rows (Figure:8; scheme 2)
- Leave a space of 115-145 cm inside block between paired rows of 'R' line seedlings for transplanting 6-8 row blocks of 'A' line seedlings.
- Transplant 2-3 seedlings per hill with a row-to-row distance of 30 cm and plant-to-plant spacing of 15 cm.

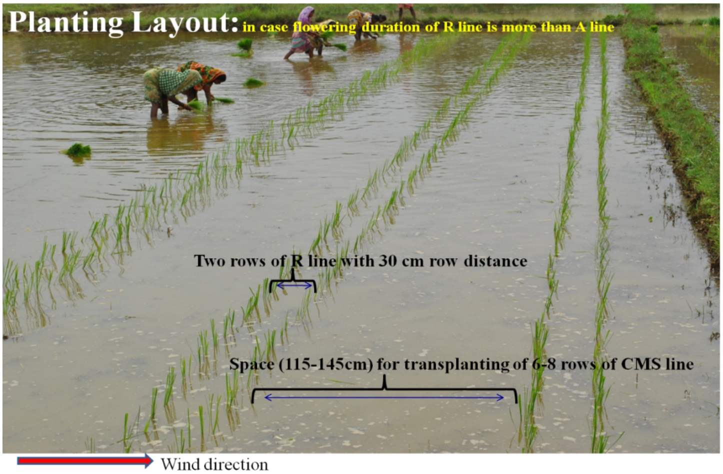


Figure 8; scheme 2: Planting layout of R line: in case R line has more flowering duration

Figure 8; scheme 3: Planting layout of R line: in case R and CMS line has same flowering duration

9.6.4. Transplanting of CMS line (A line)

- Transplant 'A' line seedlings in blocks of 8 rows in between the paired rows of 'R' lines (Scheme-1, Figure: 8b)
- Transplant with 1-2 seedlings per hill at a spacing of 15cm x 15cm
- Always keep 20 cm wide space between A line rows and nearest R line row.

9.7. Roguing

The purity of hybrid rice seeds used in commercial production must be more than 98%. To meet this requirement, the purity of the restorer and CMS lines must be more than 99%. Therefore, in addition to ensuring strict isolation, it is necessary to remove all rogues from the seed production plots. Roguing is the removal of undesirable rice plants from the hybrid seed production plots. Undesirable rice plants are those plants either in A or R line rows that differ from plants that are true to type. Roguing helps to prevent the off-types from cross-pollinating the true to type A line plants and thus enhancing the purity of hybrid seed. The undesirable plants come from many sources. They may be voluntary plants from the previous crop. Contamination due to improper isolation also results in the occurrence of off-types. Admixing during the process of harvesting, threshing, packing and handling is also possible for which the off-types occur. Therefore, due care is to be taken to remove the off-types during the cropping season. Roguing can be done at any time during the crop stage. Off-type rogues can be removed whenever they are identified-earlier the better. The important stages for roguing are maximum tillering, flowering and just before harvesting.

9.7.1. Roguing at maximum tillering: We can identify the off-types by their morphological differences from the true to type plants. Therefore, it is essential to know the characteristic features of parental lines, which help in easy identification of rogues and efficient roguing. As a basic step, any plant found outside the rows (figure 9) has to be removed as they may be volunteer plants. Remove all those plants which are either too tall or too short than the seed or pollen parent. We can also identify the off-type plants by difference in their leaf blade size, shape and leaf sheath colour.

9.7.2. Roguing at flowering: Roguing at flowering is extremely important as it is the stage when we can identify many off-types which look similar to the parental lines during the early stages of growth. All the off-type plants that flower very early or very late are to be removed. The plants which differ from parental line plants in respect of leaf size, shape, angle, panicle shape, size and pigmentation are to be carefully removed. Remove all the plants from A line that have plumpy yellow anthers. Plants in the A line should not have fertile pollen. The off-types in A lines can also be distinguished from their fully exserted panicles (imperfect panicle exsertion occurs in CMS). Care should be taken to remove the plants, which are highly infested with pests and diseases.

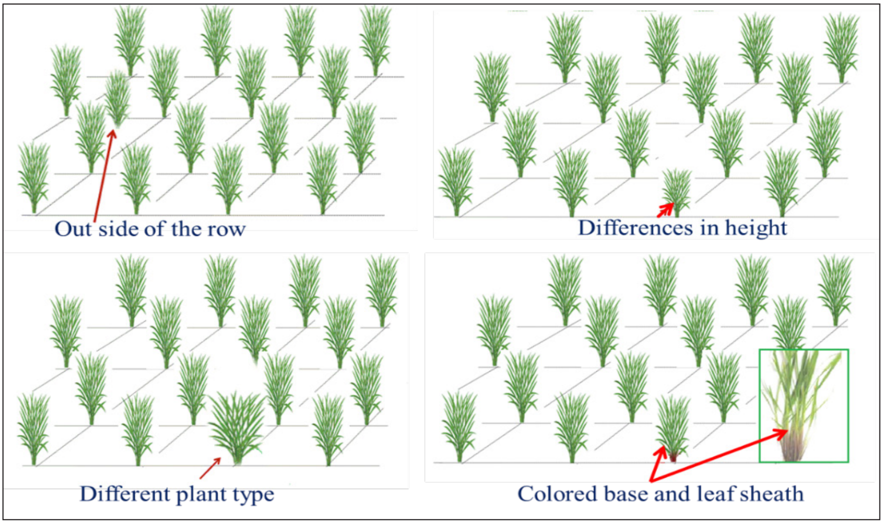


Figure 9: Roguing at tillering stage

Figure 10: Roguing at flowering stage

9.7.3. Roguing just before harvest: This is the last opportunity to keep away the off-types in order to maintain high purity. Before harvesting, the plants in A line rows are to be thoroughly checked and those plants which show normal seed set (more than 70% seed set) are to be removed. It is necessary to remove all the off-types that have different grain characters as compared to that of A line plants. The grain size, shape, colour and pigmentation of A line plants have to be critically examined for effective roguing.

9.8. Out-crossing encouragement:

Most of the male sterile lines based on WA cytoplasm have imperfect exsertion of panicle. As a result, as much as 15-20% spikelets remain enclosed in the flag leaf and are not exposed for out crossing. By adopting following methods, the exsertion of the panicles can be promoted to a great extent.

9.8.1. Application of gibberellic acid (GA3): It is an efficient and effective plant growth regulator, which stimulates the cell elongation, thus can be used to enhance panicle exsertion in CMS line. Besides, GA3 has the following favourable effects:

- Increases the duration of floret opening
- Increases stigma exsertion and receptivity
- Promotes plant height
- Influences flowering and hence flowering in parental lines can be adjusted
- Widens the flag leaf angle
- Promotes exsertion and growth rate of secondary and tertiary tillers.

In hybrid seed production plots of rice, 8-10% panicle emergence stage is most appropriate for first spraying (40%) and the remaining 60% of GA3 should be sprayed on the following day. The ideal time for spraying is from 8 to 10 AM and from 4 to 6 PM. Spraying should be avoided during cloudy weather and when the wind velocity is high. A dose of 45-60 g/ha of GA3 is optimum. The hormone does not dissolve in water and it should be dissolved in 70% alcohol (1 g of GA3 in 25-40 ml of alcohol).

9.8.2. Flag leaf clipping: Normally the flag leaves are erect and longer than the panicles and they come on the way of easy pollen dispersal thus affecting the out-crossing rate. The clipping of flag leaf helps in free movement and wide dispersal of pollen grains to give higher seed production. The flag leaves should be clipped when the main culms are in booting stage. Only half or two-third portion of flag leaf should be removed (see in figure 11). However, flag leaf cutting is not advisable in the plots infested with diseases as this operation may spread the disease further.

Figure 11: Flag leaf cutting

9.8.3. Supplementary pollination: Rice is basically a self-pollinated crop and hence in order to enhance the extent of out-crossing there is a need to go for supplementary pollination. Supplementary pollination is a technique of shaking the pollen parent so that the pollen is shed and effectively dispersed over the A line plants. Supplementary pollination can be done either by rope pulling or by shaking the pollen parent with the help of two bamboo sticks (see in Figure 12. Scheme1 & 2). Timing and frequency of supplementary pollination is very important. The first supplementary pollination should be done at peak anthesis time i.e. 8.30 a.m. to 10.30 a.m. when 30-40 % of the spikelets are opened. This process is repeated 3–4 times during the day at an interval of 30 minutes. Supplementary pollination has to be done for 7-10 days during the flowering period.

Scheme 1: Supplementary pollination through stick shaking

Scheme 2: Supplementary pollination through rope pulling

Figure 12: Supplementary pollination through stick shaking and rope pulling

9.9. Fertilizer management

Fertilizer management is very crucial activity in hybrid seed production. Imbalanced dose and improper timing of application may affect the flowering synchronization in parental lines. Therefore, it should always be done on the basis of soil fertility test report. In India, recommended dose of N: P: K for Kharif season is 100:50:50 kg/ha whereas for Rabi it is slightly more i.e. 120:60:60. Like hybrid rice cultivation, nitrogen in seed production plot should also be applied in four equal split doses (25% of total at each time). First dose should be applied just before the transplanting as basal, second dose at maximum tillering, third at panicle initiation (20-25 days before flowering) and fourth at milking stage (5 days after flowering). Whole phosphatic fertilizer should be applied as basal but potash in two split i.e. ¾ of total as basal and ¼ at PI growth stage along with third dose of nitrogen. Extra nitrogen application causes delayed flowering, hence it should be restricted.

9.10. Irrigation and other intercultural practices

Three centimeter water layer up to 12-15 days of transplanting and 5-6 centimeter up to dough stage should be maintained, which ensure proper growth and development in rice. Within ten days after transplanting gap filling should be done.

Weed management should be done either by two-time manual weeding (first after 21 days and second after 42 days of transplanting) or chemically by applying Butachlor @ 1.5 l/acre within 48 hrs after transplanting; Benthiocarb (50 EC) @ 3l/ha or Anilofos (30 EC) @ 3 l/ha within 3-4 days after planting; Eraze-strong or Segment granules @ 4 kg/acre with sand after 8 day of transplanting.

9.11. Plant protection

Rice is prone to many insect pests, diseases and other nutritional disorders, which cause great loss in production and seed quality. Therefore, preventive measures before severe damage in field should be taken to stop/eradicate such problems. Some chemical methods which are given in Table 11 may be utilized in successful management of major rice problems.

Table 11: Important plant protection measures

Name of insect	Management practice
Gundhi bug	Spray chloropyrifos 20%+cypermethrin 2% EC @ 1 L in 200L water. Apply Malathion 5 % dust @ 6-8 kg/acre at morning time.
Stem borer	Apply Cartap hydrochloride 50 SG/ Fipronil 5 SG @1kg/ha in 200 litres water at 15 days intervals.
Plant hopper	Spray the Imidaclorpid 17.8% EC @ 1.2 L/ha
Rice hispa	Spray the chloropyriphos+supermethrin solution or qunolphos 25 EG @ 1.25 L in 200L water.
Name of diseases	**Management practice**
Bacterial leaf blight	Spray Streptocyclin/Agrimycin 60 or 80g+500g blitox or phytolon or fupravit in 500 litres of water 2-3 times at 10-15 days interval.
Blast and sheath blight	Early sowing and less nitrogen application may allow the crop to escape from blast and sheath blight. Spray fungicides like tricyclozol, hexaconozol or propiconozol @ 200ml/acre in 200 litres of water
False smut	Seed treatment with Thiram+ Carbendazim (2:1 ratio) @ 3 g/kg seeds Spray Tricyclozol 75% WP @ 1.5 g/litre water
Khaira disease	Apply Zinc sulphate @ 20-30 kg/ ha.
Brown spot	Spray one of these: Carbendazim (0.1%), Diathane M 45(0.25%), Tilt (0.1%), or hinosan (0.1%) 2-3 times at 10-12 days interval

9.12. Harvesting, threshing and processing: From the point of view of maintaining high purity, extreme care is needed while harvesting, threshing and processing of the hybrid rice plots.

9.12.1. Harvesting: All R line rows are to be harvested first (see figure 13). The R line harvest is to be removed and kept in a safe place separately. The left over R line panicles in the field should also be removed. After R line harvesting, a final roguing in seed parent has to be done carefully, removing the plants showing more than 70% seed setting. Then the seed parent plants are to be harvested.

Figure 13. Harvesting: first B/R lines are harvested. Then final roguing in A line rows followed by harvesting

9.12.2. Threshing: During threshing, the 'A' line parent and 'R' line parent harvests must be kept separate from each other. The A and R lines should be threshed separately. Before starting threshing, all the threshing equipment, threshing floor and tarpaulin to be thoroughly cleaned.

New gunny bags are to be used for storing the seeds. Two labels for each bag need to be prepared– one to place inside the bag and one to attach to the bag outside. Each label should contain the following information.

- Name and Address
- Name of the parent
- Name of the location
- Season and year
- Date of harvest

9.12.3. Yield: By following the appropriate hybrid seed production procedure, farmers can get 1.5-2.5 ton/ha hybrid seed yield (with an average of 2.0 tonnes/ha).

9.12.4. Seed drying and storage: Hybrid seed must be dried up to 12-13% moisture content and stored in cool place. Less moisture helps the seed to maintain their longevity, vigor and health for a longer period.

10. Suitable area for hybrid rice seed production

Hybrid rice seed production requires specific climatic as well as parental lines specificity. Earlier Telangana State was known for hybrid rice seed hub with more than 80 percent of the seed being produced in Karimnagar, Warangal, Nizamabad, Khammam, and Nalgonda districts. Ideal climatic conditions (24-30^{0}C temperature, >70 RH%, moderate wind velocity, 2-3m/sec), progressive and receptive seed growers and active presence of the private sector seed agencies in and around Hyderabad are the main reasons for large-scale hybrid rice seed production in these areas. Recently, with the efforts of state government along with research institutions its seed production area is extended in the states of Odisha, West Bengal, Tamil Nadu, Maharashtra and Terai belt of Uttar Pradesh and Uttarakhand which might be fulfill the demand (Table-12), 3.0 lakh tones for country's 20 mha rice area with 100% SRR (seed replacement rate).

Table 12: Climatic similarity of selected districts of Odisha, West Bengal and Telangana

Place		Jan		Feb		March		April		May	
		Temp	RH	Temp	RH	Temp	RH	Temp	RH	Temp	RH
Odisha	Bargarh	20	57	23	48	28	39	31	38	34	42
	Malkangiri	21	62	23	54	27	51	30	53	31	58
	Kalahandi	21	62	23	54	27	51	30	53	31	58
	Keonjhar	21	64	24	63	28	63	30	66	31	71
	Dhenkanal	23	68	26	64	30	66	32	69	32	72
	Sambalpur	20	61	23	55	27	45	32	40	35	40
	Cuttack	22	60	25	62	29	65	30	67	32	62
	Khordha	23	60	24	61	29	63	31	66	32	65
	Balasore	21	64	24	63	28	63	32	66	32	71
	Rayagada	20	62	23	54	29	51	31	53	31	58
Uttara-khand	US Nagar	14	62	17	57	23	51	29	38	33	36

Uttar Pradesh	Basti	16	74	18	62	23	48	29	42	31	46
	Bahraich	15	66	18	62	23	42	29	33	32	44
	Lakhimpur	15	66	18	62	23	42	29	33	32	44
	Gorakhpur	16	74	18	62	23	48	29	42	31	46
Bihar	Araria	16	-	17	-	20	-	15	-	17	-
West Bengal	Medinipur	21	64	24	63	28	63	30	66	31	71
	Bardwan	19	60	22	53	27	43	31	42	32	55
Telanga-na	Karimnagar	23	60	25	55	27	53	30	52	33	44
	Warangal	22	60	24	55	28	53	30	52	33	44
	Kurnool	20	52	24	45	28	41	33	41	35	44

11. Economic advantage of hybrid seed production:

Inspite of being more cumbersome and high input intense practice, hybrid rice seed production is a profitable venture. It creates additional job opportunity (requires 100-105 more man days) and provides more net income (around Rs. 75000/ha net income, 70% more than the unit production cost) as compared to seed production of HYV (Rs. 13000/ha, only 18% more than production cost) (see Table-13). The market price of hybrid seed is Rs. 250-270/ kg. The farmers producing the hybrid seed get only Rs. 80-90/kg. In case of low production (<5 quintal/ acre) farmers get minimum Rs. 45000 as compensation from seed production agencies.

Table13: Cost analysis of hybrid rice seed

Item		Quantity/Number (per hectare)	Cost/income (in Rs.)	
			Hybrid seed	HYV
Seed cost	Male	5 kg @ Rs. 50/kg	250	2000
	Female	15 kg @ Rs.400/kg	3000	Nil
Labour cost		250/145 @ Rs. 350/labour/day	50000	29000
FYM and fertilizer cost		N:P:K (100:50:50) (based on market price)	5400	5400
Irrigation		18-20 Irrigation (weekly) @ Rs.1500/ha/irrigation)	30000	30000
Gibberellic acid			2000	Nil
Others			15000	10000
Total cost			1,05,650	76,400
Average production			2.0 t/ha	4.5
Gross income		*Price @ Rs. 90/kg and Rs. 20/kg	1,80,000	90,000
Net income			74,350	13600

* Price of seed is the price given to the farmer.

12. Package of practices for hybrid rice cultivation

Hybrids are highly input responsive and suited to specific to area; suitable agronomic management practices are to be followed to obtain the potential yield of the hybrids. Therefore, while cultivation following point need to be undertaken:

12.1. Selection of suitable hybrid variety

Rice hybrids perform better in dry season than in wet season. As it is location specific, so, suitable hybrids should be chosen for different locations and ecosystems (Table 2). Procure fresh hybrid seeds each time only from approved seed agencies before raising the crop.

12.2. Nursery Bed Preparation

- Plough the seed bed area twice when the land is dry. Impound water for four to five days. Drain excess water. Puddle the area twice or thrice and level it by laddering.
- Prepare raised and leveled wet nursery beds of 1 m width with provision of drains of 30 cm width between the beds. Apply NPK @ 500: 500: 500 g/ 100 m^2 of nursery area and 100 kg of farmyard manure (FYM) for every 100 m^2 of nursery area before final land preparation.
- Use 20-25 g of seeds per 1 m^2 of nursery area. Nursery area of 600 m^2 is required for one hectare of main field.

12.3. Selection of Seeds

- Use faithfully labeled hybrid seeds.
- As hybrid seeds are light, never use salt solution for discarding light and half-filled grains before sowing. These grains normally have good germination.

12.4. Seed Rate

As the test weight of this hybrid is low, twelve to fifteen kg of hybrid rice seeds are sufficient to transplant in one hectare of land.

12.5. Seed Treatment

- Treat the seeds with Carbendazim (Bavistin) @2 g/kg of dry seeds after soaking in water for 24 hours.
- Spread the treated seeds on a hard floor under shade. Cover with wet gunny bag and straw and sprinkle water 2-3 times a day. Seeds will sprout in one to two days.

12.6. Time and Method of Sowing

- The right time for sowing seeds is mid-June for wet season and 1st week of December for dry season. Sowing in rabi season should not be delayed as there can be erratic flowering under delayed sowing.
- Sow the sprouted seeds on leveled and drained wet nursery beds with no standing water.

12.7. Nursery Management

- Irrigate with a thin film of water two to three days after sowing of sprouted seeds. Give light irrigation afterwards.
- After 15 days of seedling growth, apply Carbofuran (Furadan 3G) @ 250 g/ 100 m^2 of nursery.
- Keep the nursery weed-free.

12.8. Land Preparation

- Irrigated medium land with drainage facility is suitable for growing hybrid rice.
- Apply and incorporate 5 t/ha of FYM compost during the dry ploughing.
- Irrigate the field and puddle 7 to 10 days before transplanting to incorporate the weeds, if any. Puddle the land again, and level it by laddering prior to transplanting.

12.9. Transplanting

- Uproot seedlings and dip the roots of the seedlings in Chlorpyriphos solution @ 1 ml/ litre of water, overnight before transplanting.
- Transplant 25 to 30 days old seedlings erect at a shallow depth of 2 to 3 cm on puddled and leveled land (with no standing water) @ one to two seedlings/hill with a spacing of 20 cm (row-to-row) and 15 cm (plant-to-plant) or 15x15 cm between plants and rows. Rows should preferably be in the north-south direction.

12.10. Fertilizer Application

- Apply NPK @ 100: 50: 50 kg/ha in wet season and 120: 60: 60 kg/ha in the dry season. Soil test based fertilizer application especially for P and K is preferred over blanket dose.
- Apply one fourth of total N, entire amount of P and three fourths of K as basal after draining out the standing water but before final puddling. Top-dress the remaining N in three equal splits, each at three weeks after transplanting, panicle initiation (80 days from the date of sowing) and panicle emergence stages. Also apply remaining one fourth of K at panicle initiation.

12.11. Irrigation and cultural Practices

- Irrigate the field two days after transplanting. Maintain continuous shallow submergence to a water depth up to 5 cm till mid-grain filling stage.
- Complete gap filling to replace dying plants within 7 to 10 days after transplanting.
- Weed out the rice field at least twice, once at 21 days after transplanting (DAT) and again at 42 DAT.

12.12. Plant Protection

- Protect the crop from insect pests and diseases with regular monitoring of pest attacks and by following need based pesticide application.
- While spraying pesticide, use 500 liters of water/ha in case of power sprayer. Keep the field bund clean to minimize disease and pest attack.

Insect pest control

- Give one application of Furadan 3G @30 kg/ha or Thimet 10 G @ 10 kg ha at three weeks after transplanting and then spray applications of Monocrotophos 36 EC @1.5 Litres/ha or Chlorpyriphos 20 EC @ 2.5 Litres/ha twice at
- 15 days' interval thereafter, to keep the crop free from insect pests.
- For the control of Gundhi bug, apply Chlorpyriphos @ 25 kg/ha or spray Monocrotophos @ 1.5 litres ha.
- For the control of leaf folder, spray Quinalphos 25EC @ 2 litres/ha.

Disease Control

- For control of fungal diseases such as blast and brown spot spray 0.1 % Hinosan or 0.1 % Bavistin. Sheath blight can be controlled by spraying Sheath mar @ 2ml/litre.
- For control of bacterial diseases such as bacterial leaf blight (BLB) and bacterial leaf streak, drain the field, and apply an extra dose of K fertilizer @20 kg/ha. Delay top dressing of N.
- For control of viral diseases such as Tungro and Grassy stunt remove the infected plants and control the insect vector by applying Furadan @ 30 kg/ha.

12.13. Harvesting, Drying and Storage

Drain out water from the rice field after 15 days from the milk formation stage. Harvest the crop when 80% of the grains in panicles are ripened. Dry the harvested paddy. Thresh with paddle thresher or power thresher. Clean paddy grains by winnowing. Dry gradually under shade. Store the rice in improved storage bins.

12.14. Points to remember

- Never use the harvested hybrid rice grains for raising the next crop.
- Apply N in four equal splits at basal, 21DAT, PI and panicle emergence.
- Apply K in two splits 3/4th in basal and 1/4th at PI.
- Nursery sowing should be very thin (20gms/sqm) to get robust seedlings.

Transplant only one or two seedlings /hill at 15cmx15cm or15cm x20cm.

Note: Always use fresh hybrid seeds, avoid hybrid rice product of own field for next year sowing.

Table 14: List of license given for commercialization of NRRI's hybrids

Sl. No.	Name of the variety/hybrid/technology	Name of the Institute/company	Duration of MOU
1	Ajay (CRHR 7)-Hybrid	Nodai Seed India Pvt. Ltd., Gurgaon	3 years (up to 2010)
2	Rajalaxmi (CRHR 5)-Hybrid	Nodai Seed India Pvt. Ltd., Gurgaon	3 years (up to 2010)
3	Ajay (CRHR 7)-Hybrid	Annapurna Seeds Pvt. Ltd., Kolkata	3 years (up to 2011)
4	Rajalaxmi (CRHR 5)-Hybrid	Annapurna Seeds Pvt. Ltd., Kolkata	3 years (up to 2011)
5	Ajay (CRHR 7)-Hybrid	Vikky Agrisciences Pvt. Ltd., Hyderabad	3 years (up to 2012)
6	Rajalaxmi (CRHR 5)-Hybrid	Vikky Agrisciences Pvt. Ltd., Hyderabad	3 years (up to 2012)
7	Ajay (CRHR 7)-Hybrid	Signet Crop Sciences, Pvt. Ltd., New Delhi	3 years (up to 2012)
8	Rajalaxmi (CRHR 5)-Hybrid	Signet Crop Sciences, Pvt. Ltd., New Delhi	3 years (up to 2012)
9	Parental lines of Ajay- Hybrid	IFSSA, Hyderabad	5 years (up to 2015)
10	Parental lines of Rajalaxmi- Hybrid	IFSSA, Hyderabad	5 years (up to 2015)
11	Ajay (CRHR-7)-Hybrid	Sansar Agropol Pvt. Ltd. Bhubaneswar	3 years (up to 2013)
12	Rajalaxmi (CRHR-5) Hybrid	Sansar Agropol Pvt. Ltd. Bhubaneswar	3 years (up to 2013)
13	Hybrid rice Rajalaxmi-(CRHR 5)	Nath Biogene(I) Ltd., Aurangabad, Maharashtra	3 years (up to 2015)
14	Hybrid rice CR Dhan 701 (CRHR-32)	Nath Biogene (I) Ltd., Aurangabad, Maharashtra	3 years (up to 2015)
15	Hybrid rice Ajay-(CRHR-7)	PAN Seeds Pvt. Ltd., Kolkata	3 years (up to 2015)
16	Hybrid rice Rajalaxmi -(CRHR 5)	PAN Seeds Pvt. Ltd., Kolkata	3 years (up to 2015)
17	Hybrid rice Ajay-(CRHR 7)	Vikkys Agrisciences Pvt. Ltd., Hyderabad	3 years (up to 2015)
18	Hybrid rice Rajalaxmi-(CRHR 5)	Delta Agrigenetics Pvt. Ltd., Hyderabad	3 years (up to 2015)
19	Hybrid rice CR Dhan 701 (CRHR-32)	Delta Agrigenetics Pvt. Ltd., Hyderabad	3 years (up to 2015)

20	Hybrid rice Ajay (CRHR 7)	Balaji Agri Biotech Pvt. Ltd. Paikmal, Odisha	3 years (up to 2016)
21	Hybrid rice Rajalaxmi-(CRHR 5)	Bharat Nursery Pvt. Ltd., Kolkata-5, West Bengal	3 years (up to 2015)
22	Hybrid rice Ajay- (CRHR 7)	Sai Shradha Agronomics and Husbandry Pvt. Ltd. Puri-752114, Odisha	3 years (up to 2015)
23	Hybrid rice CR Dhan 701-(CRHR-32)	Sri Sai Swarupa Seeds Pvt. Ltd., Warangal, Andhra Pradesh	3 years (up to 2015)
24	Hybrid rice Rajalaxmi-(CRHR 5)	Vibha Agrotech Pvt. Ltd., Hyderabad	3 years (up to 2015)
25	Hybrid rice CR Dhan 701-(CRHR-32)	Vibha Agrotech Pvt. Ltd., Hyderabad	3 years (up to 2015)
26	Hybrid rice Rajalaxmi-(CRHR 5)	Sansar Agropol Pvt. Ltd., Bhubaneswar	3 years (up to 2016)
27	Hybrid rice Ajay- (CRHR 7)	Sansar Agropol Pvt. Ltd., Bhubaneswar	3 years (up to 2016)
28	Hybrid rice CR Dhan 701-(CRHR-32)	GV Seeds Pvt. Ltd., Hyderabad	3 years (up to 2017)
29	Hybrid rice Rajalaxmi-(CRHR 5)	GV Seeds Pvt. Ltd., Hyderabad	3 years (up to 2017)
30	Hybrid rice CR Dhan 701-(CRHR-32)	Bioseed research India Pvt. Ltd., Hyderabad	3 years (up to 2017)
31	Hybrid rice CR Dhan 701(CRHR-32)	Delta Agri Genetics Pvt. Ltd., Telangana	3 years (up to 2017)
32	Hybrid Rice Rajalaxmi (CRHR-5)	Bhartiya Beej Nigam Pvt. Ltd., Uttarakhand	3 years (up to 2018)
33	Hybrid Rice CR Dhan 701(CRHR-32)	Nath bio-genes Pvt. Ltd.	3 years (up to 2019)
34	Hybrid Rice CRHR -5(Rajalaxmi)	Nath bio-genes Pvt. Ltd.	3 years (up to 2019)
35	Hybrid Rice CRHR-5 (Rajalaxmi)	PAN Seeds Pvt. Ltd.	3 years (up to 2019)
36	Hybrid Rice CRHR-5 (Rajalaxmi)	M/s Bharat Nursery Pvt. Ltd., Kolkata	3 years (up to 2020)
37	Hybrid Variety Rajalaxmi (CRHR 5)	Mahalaxmi Seeds Corporation, Ambedakar Chowk, Begusarai, Bihar-851 101	3 years (up to 2021)
38	Hybrid Variety CR Dhan 701 (CRHR 32)	Jay Shankar Agro Inputs Pvt. Ltd. 65, Old Subzi Mandi, Delhi -110 007	3 years (up to 2021)

Table 15: Hybrid rice released in India (1994-2020)

Sl. No.	Name of Hybrid/ IET No.	Gazette notification/ S. No.	Year	Duration	Grain type	Parent Institute	Recommended for State
1.	APHR-1	-	1994	130-135	LS	APRRI, Maruteru	Andhra Pradesh
2.	APHR-2	-	1994	120-125	LS	APRRI, Maruteru	Andhra Pradesh
3.	CORH-1	DL 33004/99; S.O. 360 (A), 1997	1994	110-115	MS	TNAU, Coimbatore	Tamil Nadu
4.	KRH-1	DL 33004/99; S.O. 1 (A), 1996	1994	120-125	LS	VC Farm, Mandya	Karnataka
5.	CNRH-3		1995	125-130	MS	RRS, Chinsurah	West Bengal
6.	DRRH-1	DL 33004/99; S.O. 401 (A)	1996	125-130	LS	DRR, Hyderabad	Andhra Pradesh
7.	KRH-2	DL 33004/99; S.O. 401 (A)	1996	130-135	LB	VC Farm, Mandya	Andhra Pradesh, Karnataka, TN, Tripura, MH, HR, UK & RJ
8.	Pant S Dhan-1	DL 33004/99; S.O.425(A), 1999	1997	115-120	LS	Pantnagar	Uttar Pradesh
9.	PHB-71	DL 33004/99; S.O. 647 (A), 1997	1997	130-135	LS	Pioneer Overs. Corp.	Haryana, UP, TN
10.	CORH-2	DL 33004/99; S.O.425 (A), 1999	1998	120-125	MS	TNAU, Coimbatore	Tamil Nadu
11.	ADTRH-1	DL 33004/99; S.O.425 (A), 1999	1998	115-120	LS	TNRRI (TNAU)	Tamil Nadu
12.	Sahyadri	DL 33004/99; S.O.821 (E)	1998	125-130	LS	RARS, Karjat	Maharashtra
13.	NSD-2	DL 33004/99; S.O.425 (A), 1999	1998	125-130	LS	Faizabad	Uttar Pradesh
14.	PA 6201	NA	2000	125-130	LS	Bayer Bio-Science	Eastern states, AP, TN, Karnataka
15.	PA-6444, IET 16434	DL 33004/99; S.O.1134 (A)	2001	135-140	MS	Bayer Bio-Science	Uttar Pradesh, Bihar, AP, OD, MH

16.	Pusa RH-10	DL 33004/99; S.O.1134 (A)	2001	120-125	LS	IARI, New Delhi	Haryana, Punjab, Delhi, Western UP
17.	PRH-122 (Ganga)	NA	2001	130	LS	Paras Seeds Ltd.	Bihar, Odisha, Punjab, UP, UK
18.	RH-204	DL 33004/99; S.O.283 (A), 2003	2003	120-126	LS	Parry Monsanto Seeds	AP, Karnataka, TN, Haryana, UK, RJ
19.	Suruchi 5401	DL 33004/99; S.O.122 (A), 2005	2004	130-135	MS	Mahyco Ltd.	Haryana, AP, Karnataka, Maharashtra
20.	Pant S Dhan-3	NAe	2004	125-130	LS	Pantnagar, UK	Uttarakhand
21	NUSD-3	-	2004	130-135	LS	Faizabad, UP	Uttar Pradesh
22	DRRH-2, IET 18076	DL 33004/99; S.O.1566;	2005	112-116	LS	DRR, Hyderabad	Haryana, UK, TN & WB
23	Rajalaxmi	DL 33004/99; S.O.1572(A); 2006	2005	130-135	LS	NRRI, Cuttack	Odisha
24	Ajay, IET 18166	DL 33004/99; S.O.1572(A); 2006	2005	130-135	LS	NRRI, Cuttack	Odisha
25	Sahyadri-2	-	2006	115-118	LS	RARS, Karjat	Maharashtra
26	Sahyadri-3	-	2006	123-126	LS	RARS, Karjat	Maharashtra
27	HKRH-1	-	2006	135-139	LS	RARS, Karnal	Haryana
28	CORH-3	DL 33004/99; S.O.1178 (E)	2006	115	NA	TNAU, Tamil Nadu	Tamil Nadu
29	JKRH-401	DL 33004/99; S.O. 244 (E)	2006	130-135	LB	JK Agri. Genetics Ltd.	Bihar, WB, OD
30	KJTRH-2	-	2006	NA	NA	RARS Karjat	Maharashtra
31	Indira Sona	-	2006	125-128	LS	IGKKV, Raipur	Chhattisgarh
32	HRI-152	DL 33004/99; SO 268 (E)	2007	120	LS	Bayer Bio-Science	Punjab & TN
33	JRH-4	DL 33004/99; S.O.1178	2007	115	LB	JNKVV, Jabalpur	Madhya Pradesh
34	JRH-5	DL 33004/99; S.O.1178	2007	115	LS	JNKVV, Jabalpur	Madhya Pradesh

35	PA6129, IET18815	DL 33004/99; S.O.1703 (A)	2007	120	LS	Bayer Bio-Science	Maharashtra
36	GK-5003	DL 33004/99; S.O.1703 (A)	2008	125-130	LS	Ganga Kaveri Seeds Pvt.	Andhra Pradesh, Karnataka
37	Sahyadri-4, IET 18610	DL 33004/99; S.O.454 (A)	2008	115-120	LS	RARS, Karjat	Maharashtra, UP, WB, Punjab, HR
38	JRH-8	DL 33004/99; S.O.449 (A), 2009	2008	115-120	NA	JNKVV, Jabalpur	Madhya Pradesh
39	DRH-775, IET 19741	DL 33004/99; S.O.2187, 2009	2009	97	LS	Methelix Life Sc. Pvt, Ltd.	Chhattisgarh, JH
40	HRI-157, IET19511	DL 33004/99; S.O.2187, 2009	2009	130-135	LB	Bayer Bio-Science	Chhattisgarh, GJ, Karnataka, MP, Pondicherry, UP
41	PAC-835, IET18178	DL 33004/99; S.O.2187	2009	132	MS	Advanta India Ltd.	All India
42	PAC-837, IET19746	DL 33004/99; S.O.2187	2009	130	LB	Advanta India Ltd.	All India
43	NK-5251, IET19738	DL 33004/99; S.O.2125(A), 2012	2009	128	LS	Syngenta India Ltd.	Andhra Pradesh, GJ, Karnataka, Maharashtra, T N
44	DRRH-3, IET 19543	DL 33004/99; S.O.211 (A)	2009	131	MS	DRR, Hyderabad	Andhra Pradesh, GJ, MP
45	US-312, IET 19513	DL 33004/99; S.O.2136	2009	125-130	MS	Seed Works International	Andhra Pradesh, Bihar , Karnataka, TN & UP
46	Indam-200-017	DL 33004/99; S.O.2326, 2011	2010	120-125	LB	Indo-American Seeds	Odisha, Chhattisgarh, GJ, MH & A.P.
47	CRHR-32, IET 20852	DL 33004/99; S.O.456(A), 2012	2010	145	MS	ICAR-NRRI, Cuttack	Bihar, GJ, OD
48	27P11, IET 19766	DL33004/99; S.O.632,(A), 2011	2010	130-135	MS	PHI Seeds (P) Ltd.	Karnataka, MH

49	VNR-2245, IET20716	DL 33004/99; S.O.456(A), 2012	2011	110-115	MS	VNR Seeds Pvt. Ltd.	Chhattisgarh, TN
50	VNR-2355, IET20735	DL 33004/99; S.O.456(A), 2012	2011	130-135	MS	VNR Seeds Pvt. Ltd	Uttar Pradesh, UK, WB, MH & TN
51	US-382, IET20727	DL 33004/99; S.O.2125(A), 2012	2012	125	LB	Seed Works International	Karnataka, Tripura and MP
52	PNPH924-1, IET21255	DL 33004/99; S.O.2125(A), 2012	2012	165-170	MS	Nuziveedu Seeds Ltd.,	West Bengal and Assam
53	PNPH-24, IET21406	DL 33004/99; S.O.2125(A), 2012	2012	125-130	LS	Prabhat Agri. Biotech Ltd.	Bihar, OD and WB
54	27P31, IET21415	DL33004/99;S.O.2815/ S.O.2816	2012	130-135	MS	PHI Seeds (P) Ltd.	Andhra Pradesh, Karnataka and Chhattisgarh
55	27P61, IET21447	DL 33004/99; S.O.2125 (A), 2012	2012	130-135	MS	PHI Seeds (P) Ltd.	Andhra Pradesh, Karnataka, TN, UP, JH & Chhattisgarh
56	25P25, IET 21401	DL 33004/99; S.O.2125 (A), 2012	2012	120	LS	PHI Seeds (P) Ltd.	Uttarakhand, Karnataka and JH
57	JKRH-3333, IET20759	NA	2012	135-140	MS	JK Agri. Business Ltd.	West Bengal, Bihar, Chhattisgarh, GJ and AP
58	HRI 169, IET 21411	DL 33004/99; SO 269 (E)	2012	125	LS	Bayer Bio-Science	Bihar, Chhattisgarh, TN, AP & GJ
59	RH 1531, IET21404	NA	2012	125	LS	Devgen Seeds	Madhya Pradesh, UP, AP, Karnataka & MH
60	CO(R)H-4, IET21449	DL33004/99;S.O.1708(E), 2012	2012	130-135	MS	TNAU, TamilNadu	Tamil Nadu
61	Sahyadri-5	NA	2012	140-145	LS	RARS, Karjat	RSL Konkan region, MH
62	Arize Dhani , IET21415	DL33004/99;S.O.2815/S.O. 2817	2012	140-145	MS	Bayer Bio-Science	Odisha
63	27P52, IET21433	DL 33004/99; S.O.2818	2013	135-140	LB	PHI Seeds (P) Ltd.	Uttarakhand, Chhattisgarh, OD, GJ & AP

64	27P63, IET21832	DL 33004/99; S.O.2819	2013	130-137	MS	PHI Seeds (P) Ltd.	Chhattisgarh , UP, AP & Karnataka
65	KPH-199	DL 33004/99; S.O.2810	2013	NA	MS	Kaveri seed co ltd	Chhattisgarh , MP, AP
66	KPH-371	DL 33004/99; S.O.2821	2013	NA	MS	Kaveri seed co ltd	Chhattisgarh , J&K, Karna-taka, Kerala
67	VNR 2375Plus	DL33004/99;S.O.2822	2013	NA	NA	VNR Seeds Pvt.Ltd.	UK, Punjab, MH, Bihar & Karnataka.
68	US-314, IET21777	DL 33004/99; S.O.2823	2013	125-130	NA	Seed WorksIntl Pvt. Ltd.	West Bengal, Bihar, AP & UK
69	US 305, IET21827	DL 33004/99, SO 244 (E)	2013	NA	NA	Seed Works Intl Pvt. Ltd.	Andhra Pradesh, TN, MH
70	PAC 807, IET	DL 33004/99; SO 244 (E)	2013	NA	NA	Advanta India Ltd.	Chhattisgarh
71	Ankur-7434	DL 33004/99; SO 244 (E)	2013	135	NA	Ankur Seeds Pvt. Ltd.	Chhattisgarh
72	27P63	NA	2013	130	MS	PHISeedsPvt.Ltd.	Andhra Pradesh,Chhattis-garh, Karnataka,UP
73	PAC-801	DL 33004/99; SO 1146 (E)	2014	NA	NA	Advanta seed Pvt. Ltd.	Uttar Pradesh
74	Arize-6444G	DL 33004/99; SO 268 (E)	2015	NA	135-140	BayerCropScience	Assam,Chhattisgar-h,OD,UP,Bihar,Megha-laya, Karnataka & TN
75	HRI -178	DL 33004/99; SO 268 (E)	2015	NA	NA	BayerCropScience,	Punjab, Chhattisgarh and UP
76	KRH-4, IET 22402	-	2016	97	MS	RRS, Mandya	Gujarat, MH
77	KPH-460, IET 22938	-	2016	100	MS	Kaveri Seed Pvt. Ltd.	Gujarat, Maharashtra, AP, TS, Karnataka, TN
78	KPH-467, IET 24142	S.O. 3540(E), 2016	2016	96	SB	Kaveri Seed Pvt. Ltd.	Maharashtra, Chhattisgarh, MP

79	KPH-272, IET 24028	S.O. 3540(E), 2016	2016	96	MS	Kaveri Seed Pvt. Ltd.	Telangana, TN, Karnataka
80	NK-16520, IET24146	S.O. 3540(E), 2016	2016	102	LB	Syngenta India Ltd.	Chhattisgarh, UP, Bihar, JH, OD & TS
81	Sahayadri-5 (IET20884)	S.O. 2238 (E), 2016	2016	110-115	LS	RARS, Karjat	Maharashtra
82	ADV-8301, IET22410	S.O. 2238 (E), 2016	2016	93	MS	Advanta Limited	Gujarat, MH, AP and TS
83	Arize Swift, IET18157	S.O. 3540(E), 2016	2016	95	LB	BayerCropScience	Madhya Pradesh
84	JRH-19	S.O. 2238 (E), 2016	2016	NA	NA	NA	Madhya Pradesh
85	Pan-802, IET23498	DL 33004/99; SO 2805(E)	2017	120-122	LS	PAN Seed, Kolkata	West Bengal
86	PAN-2423, IET 21395	DL 33004/99; SO 2805(E)	2017	120-122	SB	PAN Seed, Kolkata	West Bengal
87	Indam200-022, IET 20710	DL 33004/99; SO 2805(E)	2017	115	MS	Indo-American seeds	Madhya Pradesh
88.	Arize Swift Gold	DL 33004/99; SO 2805(E)	2017	115-120	MS	BayerCropScience	Haryana, UK, UP & Gujarat
89	Arize Tej Gold, IET 24120	DL 33004/99; SO 2805(E)	2017	95	LS	BayerCropScience	Punjab, HR & UK
90	Arize 6129	DL 33004/99; SO 2805(E)	2017	NA	NA	BayerCropScience	Madhya Pradesh &UP
91	Arize 6129 Gold	DL 33004/99; SO 2805(E)	2017	115-120	NA	BayerCropScience	Chhattisgarh &UP
92	28P09, IET 24156	DL 33004/99; SO 2805(E)	2017	135	MS	PHI Seeds (P) Ltd.	Odisha, WB, UP, Assam, Chhattisgarh, Maharashtra, Gujarat, TN & AP
93	JKRH-3333	DL 33004/99; SO 2805(E), 2017	2017	110	MS	JK Agri Genetics Ltd.	Madhya Pradesh, WB, Bihar, Chhattisgarh, GJ and AP

94	27P22, IET 24122	DL 33004/99; SO 2805(E), 2017	2017	96	MS	PHI Seeds (P) Ltd.	Punjab and Haryana
95	NPH-8899, IET 23494	DL 33004/99; SO 2805(E), 2017	2017	138	SB	Nuziveedu Seeds	Uttar Pradesh, Bihar, Assam
96	GK-5022, IET 23445	DL 33004/99; SO 2805(E), 2017	2017	93	LS	Ganga Kaveri Seeds Pvt. Ltd.	Bihar and Chhattisgarh
97	27P36	DL 33004/99; SO 2805(E), 2017	2017	130	LB	PHI Seeds (P) Ltd.	Bihar, MP, JH, Chhattisgarh and OD
98	28P67, IET 24879	DL.-33004/99, S.O. 1379(E), 2018	2018	130-135	LB	PHI Seeds (P) Ltd.	Uttar Pradesh, Bihar, JH, OD, WB, Chhattisgarh and MH
99	28S41, IET 24891	DL.33004/99, S.O. 1379(E), 2018	2018	135-140	MS	PHI Seeds (P) Ltd.	Uttar Pradesh, OD, WB, JH, MH, MP, Chhattisgarh, TS, AP, Karnataka and TN
100	27P37, IET 24844	DL.33004/99, S.O. 1379(E), 2018	2018	125-130	LB	PHI Seeds (P) Ltd.	Chhattisgarh, MP & MH
101	Bio-799, IET 22919	DL.33004/99, S.O. 399(E), 2018	2018	135-140	LB	Bio-seeds, Pvt. Ltd.	Odisha, Bihar, JH, WB & UP
102	CNRH-102	NA	2018	130	MS	RRS, Chinsurah	West Bengal
103	GRH-2	DL.33004/99; S.O. 3220(E), 2019	2019	135	MS	Navasari state University, Gujarat	Gujarat
104	LG 93.01, IET 24949	DL.33004/99, S.O. 3220(E), 2019	2019	NA	NA	Limagrain Seeds Pvt. Ltd.	Uttar Pradesh.
105	PAC 801	DL.33004/99; S.O. 3220(E), 2019	2020	NA	NA	Advanta Limited	Madhya Pradesh
106	MP-3030, IET25764	NA	2019	NA	NA	Mahindra Agribusiness	Haryana, UK, MH & GJ
107	US 380, IET25728	NA	2019	NA	NA	US Seedworks	Chhattisgarh & MP

108	US-303, IET 25804	NA	2019	NA	NA	US Seedworks	Chhattisgarh, MH, MP
109	SAVA-134, IET 24797	NA	2019	NA	NA	Savannah Seeds Pvt. Ltd.	Haryana, Punjab, Assam & UK
110	MRP-5222, IET25269	NA		NA	NA	Maharashtra Hybrid Seeds Pvt. Ltd.	West Bengal, Bihar, OD & MH
111	RH-9000Plus, IET2493 1	NA	2019	NA	NA	Devgen Seeds Lim-ited	Maharashtra
112	MRP-5626, IET 26198	NA	2019	NA	NA	Maharashtra Hybrid Seeds Pvt. Ltd.	Bihar
113	MRP-5433	NA	2019	130	Fine	MAHYCO Pvt. Ltd.	NA
114	PAC-8744Plus, IET 25785	S.O No.3540 (E), 2016	2020	NA	NA	Advanta Limited	Chhattisgarh
115	Chhattisgarh RH-2	NA	2020	NA	NA	IGKV, Raipur	Chhattisgarh
116	KPH-471, IET 25746	NA	2020	NA	NA	Kaveri seed company Ltd.	Haryana, Punjab, UK, TS, Karnataka & Kerala
117	RH 150025, IET 26477	NA	2020	120	LB	Devgen Pvt. Ltd.	Chhattisgarh
118	JKRH 2354, IET26468	NA	2020	120-125	LB	JK Seeds Pvt. Ltd.	NA
119	JKRH 2154, IET 24914	NA	2020	120	LB	JK Seeds Pvt. Ltd.	NA
120	28S44	NA	2020	NA	NA	PHI Seeds (P) Ltd.	NA
121	27P27	NA	2020	NA	NA	PHI Seeds (P) Ltd.	NA
122	Indam-100-012, Aromatic	NA	2020	120	LB	Indo-American Seeds	NA

References

1. Dash AK, Rao RN, Rao GJN, Verma RL, Katara JL, Mukherjee AK, Singh ON and Bagachi TB (2016) Phenotypic and Marker-Assisted Genetic Enhancement of Parental Lines of Rajalaxmi, an Elite Rice Hybrid. Front. Plant Sci. 7:1005. doi: 10.3389/fpls.2016.01005.
2. IRRI (1997) Hybrid rice manual, International Rice Research Institute, Manila, Philippines, pp. 194.
3. Mao CX, Virmani SS and Kumar I (1998) In: Technology innovation to lower the cost of hybrid seed production. Advances in hybrid rice technology. Proceeding of third international symposium on hybrid rice.14-16 November, 1996, Hyderabad, India. IRRI, Manila, Philippines. pp. 111-128.
4. National Food Security Mission (2010) Guidelines for seed production of hybrid rice, Gov. of India, Ministry of Agriculture, Department of Agriculture and Cooperation, pp. 44.
5. Rout D, Jena D, Singh V, Kumar M, Arsode P, Singh P, Katara JL, Samantaray S and Verma RL (2020). Hybrid Rice Research: Current Status and Prospects, Recent Advances in Rice Research, Mahmood-ur- Rahman Ansari, IntechOpen, DOI: 10.5772/intechopen.93668.
6. Samant, TK (2014) Impact of front line demonstration on yield and economics of hybrid rice (Rajalaxmi). Indian J. Agric. Res., 49 (1) 2015: 88-91.
7. Verma RL, Katara JL, Samantaray S, Patra BC, Sahu RK, Patnaik SSC, Poonam A, Hembram B, Rao RN, Singh ON and Mohapatra T (2015) A Practical Guide for Successful Hybrid Seed Production in Rice- A Profitable Venture. Published by National Rice Research Institute, Cuttack, Odisha, Technology bulletin-114, pp 20.
8. Verma RL, Katara JL……Singh ON (2018) Harnessing Heterosis in Rice for Enhancing Yield and Quality. Rice research for enhancing Productivity, Profitability and Climate Resilience, NRRI-137-159.
9. Verma RL, Singh S, Kumar M, Bal D, Rout D, Samantaray and Singh ON (2018) Method optimization for parental line synchronization in hybrid rice seed production. Plant Archives, 18:200-204.
10. Verma RL, Singh S, Singh P, Kumar V, Singh SP and Singh ON (2017) Genetic purity assessment of indica rice hybrids through DNS fingerprinting and grow-out test. Journal of Environmental Biology, 38(6): 1321-1331.
11. Virmani SS, Chaudhary RC and Khush GS, 1981. Current outlook on hybrid rice. *Oryza.* 18:67-84.
12. Xie F and Hardy B (2010) Book ‘Accelerating hybrid rice development, International Rice Research Institute, Manila, Philippines, pp. 698.

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