Quality Seed Production and Maintenance Breeding for Enhancing Rice Yield

RK Sahu, RP Sah, P Sanghamitra, RL Verma, NKB Patil, M Jena, AK Mukherjee, MK Bag and ON Singh

SUMMARY

Indian seed production system is a robust route to mitigate the seed requirement of the country. The seed class involves Nucleus, Breeder, Foundation and Certified seed with different seed quality standard at different levels to safe-guard the production of large quantity of quality seed for sustainable agriculture. The maintenance breeding is a mandatory step for the institute who are involved in development of variety. The developer maintains the seed purity of released varieties by curbing the chance of out crossing and genetic drift. The quality seed is the first and prime requisite for grain production, which alone contribute about 30% of yield improvement. Further, seed traits such as seed dormancy, viability, priming, foliar spray etc. are being given importance to improve cultivars for seed traits. Thus, it is important to deliver a healthy, improved variety seed to meet the seed requirement of the country and to dissect the seed traits for development of cultivar to cope with changing climate. Availability of good quality seed at the right time wherever it is needed with agreeable price, very much plays a major role in the highest grain production of a nation. The Indian seed delivery system which is backed by both formal and informal seed system has a good structural network for sufficient availability of seed but, the seed replacement rate and the varietal replacement rate are under desirable limit; majority of seed requirement of our farmer is fulfilled by informal seed system is one of the major factor responsible for this. Gaps in seed systems which include non-availability of many high yielding varieties in the seed chain, non-availability of sufficient quantity of quality seed, deterioration in seed quality, long time span for seed quality testing and non-assurance of genetic purity of Marker Assisted Selection developed varieties. Possible solutions for different constraints to strengthen the seed system has been discussed in the Chapter.

1. INTRODUCTION

Seed is an enigmatic genetic capsule essential for multiplication and establishment of species from one generation to another. It is a fertilized ovule containing the plant embryo, a unit of reproduction of a flowering plant, which is capable of developing into another true-to-type such plant. Rice crop is a monocot; seed propagating, either annual or perennial; hollow internode, with tillering habit and the apex bearing the panicle. The rice seed is caryopses, comprising of embryo and endosperm. The seed surface contains several thin layers of differentiated tissues that enclose the embryo and endosperm. The palea, lemmas, and rachilla constitute the hull in Indica rice but in Japonica the hull usually includes rudimentary glumes and perhaps a portion of the pedicel.

Pure seed is the basic and important input for healthy crops and good production. Seed should be pure, free from other contaminants, and should fit within minimum seed standard as recommended. For this purpose, a seed production system in India recognizes different class of seed viz., Nucleus, Breeder, Foundation and Certified seed with different seed quality standard to safe-guard the quality of large quantity seeds of Indian farmers. The maintenance of high quality seed of a variety is referred as 'Maintenance breeding', where a breeder is maintaining the seed purity of a released variety when it undergoes production year after year. This involves maintaining morphological, physical and genetic purity of a variety for a long period of time. These efforts were highly successful in improving seed quality by curbing the chance of out crossing and genetic drift. Further, to exploit the potential yield of a rice variety, various biochemical, physiological, and management aspects were viewed under seed technological research programme. Therefore, seed traits such as, seed dormancy, viability, priming, foliar spray etc. are being given importance by the researchers to improve the cultivars. Thus, rice seed production and molecular dissection are now the researchable areas to meet the seed requirement of the country and development of cultivar to cope with changing climate. This chapter emphasizes the status of seed production in rice, seed research and way for minimizing constraints to safe-guard national seed security. The objective of the chapter is to highlight the status of (i) breeder seeds as indented by DAC-GoI, States Government, and other organizations of India, (ii)status of seed research (iii) methods and procedure involved in quality rice seed production, and (iv) constraints involved and mitigation for seed production and research.

2. IMPORTANCE OF QUALITY SEED

Seed is the first input of agricultural production on which the performance and efficacy of other inputs depend. Good quality of seeds can contribute upto 30% increase in productivity (Hasanuzzaman2015). "Good seed harvests good crop", a good seed means a seed lot that adheres to all the parameters of minimum seed standard; this seed is generally termed as quality seed. A good quality rice seed should be pure, full and uniform in size, free from weeds, insect, disease and other inert matters and more over it should be viable (>80% germination).

Timely availability of good quality seed as per the requirement plays a major role in the higher grain production of a nation. In India, 75% small and marginal farmers are lagging behind in agriculture due to unavailability of resources or inputs including seed. Therefore, a strong and vibrant seed production and supply system is indispensable for food security of the country and accelerating growth in agriculture. Seed is the highest prioritized input in agriculture, on which agriculture sustains. Over past 70 years, improvement in seed system was targeted to secure the seed quality, accessibility and availability.

A conscious thought on quality seed surfaced in1886 when channelized seed production began with the establishment of Swedish seed association. The association was mainly involved in production and distribution of quality seeds of forage crop varieties. Later near about 19th century, Dr. E Helve established a seed testing laboratory in Denmark for seed testing and certification. Canadian scientist Dr. JW Robertson in proposed the production of foundation seed in 1917. In 1919 an International Crop Improvement Association (ICIA) was formed to overlook the development of procedure and standards for quality seed production and seed certification. However, the organization was later named as Association of Seed Certification Agencies (AOSCA 1969). The ICIA in 1946 defined 4 classes of seed in forage crops, which was also adopted for other grain crops in 1968.

In India, Department of Agriculture of Uttar Pradesh state produced and distributed 150 tons of wheat seed in 1900. During that period limited seed testing facility was available at Kanpur. Later, in 1920 Government of Uttar Pradesh emphasized the production and distribution of quality seed and initiated project for establishment of seed godown in every subdivisions/tehsil. Later the Royal Commission on Agriculture reviewed the production and distribution of seed in India in 1925. In 1945 private seed company entered the seed scenario (like Sutton's for temperate vegetables) and in 1946 All India Seed Producer's Association (AISPA) was formed by private seed growers. A report of Famine Enquiry Commission (1945) and Grow-More Food Program Committee (1952) emphasized that there was a need to multiply and distribute the quality seeds of improved varieties. So, in 2nd Five Year Plan (1956–61) a shape for India's formal seed system was designed with special emphasis on production of nucleus and breeder seeds, which were used in multiplication of further class of seeds.

3. IMPETUS FOR QUALITY SEED PRODUCTION

The important developments relating to seed sector in the country are highlighted below in the Table 1.

In 1966-67 the seed production programme for wheat and maize was started and after a year (1967-68) rice crop was also included. After a huge review and recommendation, on 2nd October 1969 Indian Seed Act has been in force in India. Indian Seed Act, 1966 is an act to provide measures for regulating the quality of certain seeds for sale and for matters connected therewith. Some highlights of this act are (i) constitution of Central Seed Committee by Govt. of India to advice Central and State Governments regarding the Act., (ii) establishment of Central Seed Laboratory, (iii) establishment of State Seed Lab for seed quality analysis, (iv) provision of notification of varieties by Govt. of India, (v) minimum limits of germination and purity of seeds and compulsory label fixing, (vi) notified seed standard fixed, (vii) identifiable as seed of the variety it claims, (viii) must have minimum prescribed purity & germination, (ix) seed container must bear labels containing correct particulars of the seed, (x) establishment of Seed Certification Agency, (xi) establishment of Central

Table 1. Milestones in the development of Indian seed sector.

Year	Event	Objective/s
1952	A standing experts committee on seeds was appointed by Indian Council of Agricultural Research (ICAR).	The committee formulated a programme structure to strengthen the seed production & distribution system under which Central Govt. provided financial assistance to the states.
1956-57	State Seed Farm Project was initiated	Different states started producing foundation seeds in State Seed Farms.
1957-1965	All-India Coordinated Project for maize, wheat, pearl millets and barley	This involved production of foundation and certified seeds.
1959	An agricultural production team, by Dr. Johnson was formed	To bring uniform standards of seed certification, seed laws and establishment of Seed Testing Lab for each States.
	Planning Commission appointed a Seed Multiplication Team	To review the various aspects of seed programmes.
1960	ICAR set up a Committee	To suggest ways for developing a strong seed production programme. The Committee recommended for establishment of Central & State agencies for the production of foundation seed and an independent seed certification agencies to safe-guard the quality seed. The same committee also recommended for enactment of National Seed Act and formation of agencies for enforcement of seed act.
1963	ICAR constituted a committee	National Seeds Corporation was established and Indian Seed Act was enacted in 1966
1964	A rapid varietal release systems for improved variety	The State Variety Release Committees (SVRC) was established

Seed Certification Board to advise the Govt. of India and State Govt. on all matters relating to certification, (xii) appointment of Seed Analyst for seed analysis in State Seed Laboratory, (xiii) appointment of Seed Inspector to collect seed samples of notified kind being offered for sale for analysis, and (xiv) forfeiture of property (seeds) belonging to any person convicted under this act due to contravention of the procedures under this act.

Further, first turning point in shaping an organized seed industry was through National Seed Project (NSP) Phase-I (1977-78) which initiated the establishment of State Farms Corporation of India (SFCI), 4 State Seeds Development Corporations (SSDCs) and Breeder Seed Production (BSP) units. In the Phase-II of NSP (1985)13 additional SSDCs and 19 state seed certification agencies were established for quality seed production. After 10 years (1988-89) a New Seed Development Policy was formulated which gave access to the private individuals with strong R&D base for product development.

To achieve the food grain demand in future, it was felt that the Seed Replacement Rate (SRR) of various crops needs to be enhanced. This would require a major increase in the production of quality seeds with the involvement of both public and private sector. To safeguard the interests of Indian farmers and agro-biodiversity conservation, and to guard the exploitation of farmers by unscrupulous elements, the National Seed Policy (2002), a regulatory system, was formed. Later for regulating the production, distribution, quality of seeds for sale, import, export and to facilitate production and supply of seeds of quality and for matters connected therewith or incidental thereto, a seed bill (2004) was proposed. The government has proposed new amendments to the bill in April 2010 and November 2010, accepting most of the recommendations given by the Standing Committee. Few highlights of the Seed Bill (2004) are (i) all varieties of seeds for sale have to be registered, (ii) the seeds are required to meet minimum standards, (iii) transgenic varieties only be registered after clearance certificate as per the Environment (Protection) Act, 1986, (iv) exemption of farmers from the requirement of compulsory registration (v) farmers are allowed to sow, exchange or sell their own seed and planting material without any formalities required by registered seeds but, farmers cannot sell seed under a brand name, and (vi) provision for claim of compensation in case a registered variety of seed fails to perform to expected standards.

4. REGULATION OF SEED SYSTEM

The national seed requirement is taken care of through formal seed system (FSS) and informal seed system (ISS). Formal seed system is characterized by large scale production of seed of officially released varieties with strict quality assurance mechanism. This system is well organized and systematic, usually starts with development of different types of varieties/hybrids. The principles in the FSS are to maintain varietal identity, purity and to produce seed of optimal physical, physiological and sanitary quality (Reddy et al. 2007). Formal seed system is managed by Government body (Government Institutions, State Government Farms, University farms & KVKs) and registered seed growers (NGOs, Private Companies) whereas ISS is managed by farmers and sometimes private seed growers.

Varietal deterioration may happen with the repeated multiplication of the same variety year after year. This deterioration accommodates mixture of seeds, undesirable pollination or outcrossing, occasional mutation and genetic drift. This overall affects varietal genetic purity and crop performance. This deterioration is taken care of in the FSS through production of Nucleus, Breeder, Foundation and certified seed; but in ISS it is not well guarded. Therefore, it is required to create awareness among the farmers/seed growers to produce quality seed in their field for their own use.

It is reported that more than 85% of the total seed sown in India is produced by farmers themselves where quality seed constituted only 12% of the total seed sown each year (Reddy etal.2007) which is responsible for reduction in10-20% of yield.

5. CONSTRAINTS IN SEED PRODUCTION AND SEED RESEARCH

Indian seed production and supply system involves both Government institution and private sector including many collaborative ventures. A huge institutional framework is working for quality seed production and its distribution. Despite a healthier seed supply channel, continuous supply of good quality seeds remains as a problem from the seed producer to farmers. Therefore, farmers prefer to rely on their farm saved seeds which limits the SRR below 20% in many states. Besides, the variety replacement rate (VRR) is another section for maintaining the higher contribution in production through quality seed. More than 900 high-yielding varieties and hybrids of rice have been released for commercial cultivation, but about 318 are in the active seed production chain. The constraints involved in seed production and distribution are; seed purchase from unreliable sources, deterioration of seed quality when multiplied for long duration, unavailability of quality seeds, lower SRR or VRR, unawareness for method of seed production, time consuming seed quality testing, and sometimes non-assurance of genetic purity of MAS developed varieties. Further, the research on improvement on seed setting, seed dormancy, seed viability, seed and seedling vigour is very little which restrict varietal features and its adoption by farmer.

6. DEVELOPMENTS IN SEED SYSTEM AND SEED RESEARCH

A rationalized system for breeder seed production programme is taken up by the Indian Council of Agricultural Research (ICAR) Institutes and State Agricultural Universities (SAUs). However, certified/quality seed production programme is taken care by the National Seeds Corporation Ltd. (NSC), the State Seeds Corporations, the State Department of Agriculture, State Seed Farms, State Agricultural Universities Farms, Krishak Bharati Cooperative Ltd. (KRIBHCO), Private Seed Farms etc. to ensure quality seeds supply to farmers.

The Indian seed production programme passes through 3-4 generations of seed multiplication in a phased manner. The system provides an adequate safeguard for seed quality assurance during multiplication to maintain the purity of the variety as it flows from the nucleus seed to the seed for farmer (Certified or TL seeds). A large number of seed companies and producers are being engaged in seed channel. To regularize the system and to monitor the quality seeds produced, about 15 State Seeds Corporation, 2 National level seeds Corporations, 34 State Departments of Agriculture, 21 Seed certification agencies, 94 Seed testing laboratories, many ICAR Institutes and State Agricultural Universities are jointly working in the seed platform.

7. SEED MULTIPLICATION CHAIN OF INDIA

Once a variety is released and notified it can be included in seed chain. The chain of seed production is presented below-

Farmer (Variety wise requirements)
↓
DAO (District Agriculture Officers) (Collected the data on variety demand)
↓
DDA (Deputy Director Agriculture) (Assessment of varietal demand, crop situation demand)
↓
Director Agriculture (actual indent to be placed, new variety to be introduced)
↓
DAC (Dept. of Agriculture & Cooperation) (National Indent of seed)
↓
Breeder seed producing organization (Produce the indented quantity of breeder seeds)
↓
SSC & Director Agriculture (lifting of breeder seeds and putting in seed chain)
↓
Seed Production Chain
↓
DAO (Organization of seed distribution)
↓
Farmer (Growers)

Responsibilities of the organization that takes up seed production (as per the class of seed) and the certification norms is presented below in Table 2.

Table 2.Seed class and institution involved in seed production.

Class of seed	Institutes/Organization/Agencies	Supervision	Certification
Nucleus seed	Developer, breeder, parent institutes	Breeder, developers	No need, responsibility of parent institution or developers
Breeder Seed	Developer, breeder, parent institutes, registered organization	Breeder, developers	Members assigned by seed certification agencies
Foundation Seed	Central Government agencies, State Departments, Agriculture Universities, State Farms, Private seed companies, Farmers producer organization	Concern producer	Members assigned by seed certification agencies
Certified Seed	Central Government agencies, State Departments, Private seed companies, Farmers producer organization, Agriculture Universities, State Farms	Concern producer	Members assigned by seed certification agencies
TL Seed	Any organization and farmers	Concern producer	No need, responsibility of producer

The breeder seed production status of the last five years revealed that the rice breeder seed producing organizations have produced more than the quantity of seed demanded every year (Table3).

Table 3. Trends in indent and production of breeder seed of rice (Chauhan et al.2017).

Year	Indent (q)	Production (q)
2012-13	5267	11455
2013-14	4837	10586
2014-15	4286	7757
2015-16	5026	5449
2016-17	5119	8765

More than 300 varieties are under seed chain but, few varieties had highest indent among them. The year wise top five varieties of last five years were presented below (Table 4). Among these varieties Swarna, Cottondora Sannalu, IR-64, Mahamaya and Vijetha were released long years back and Sahabhagidhan, Swarna Sub-1 and Naveen were released recently. The old varieties are still under demand, which may be due to its higher adaptability, buffering capacity, consistent performance and also higher tolerance to stresses.

Table 4. Top five varieties indented for breeder seeds in last 5 years.

S. No.	Variety	2012-13	2013-14	2014-15	2015-16	2016-17
1.	Swarna (MTU 7029),	✓	✓	✓	✓	
2.	Cottondora Sannalu (MTU 1010)	✓	✓	✓	✓	✓
3.	IR-64	✓	✓			✓
4.	Mahamaya	✓				
5.	Vijetha (MTU 1001)	✓	✓	✓	✓	
6.	Sahabhagidhan		✓	✓	✓	✓
7.	Swarna Sub-1			✓	✓	✓
8.	Naveen (CR-749-20-2)					✓
Contribution of top most 5 varieties to total indent (%)		27.01	30.9	34.8	28.6	31.2

From 2010 to 2015 about 355.18 lakh quintal quality rice seed was supplied, which was an average of 71.03 lakh quintal per year. The year wise production chart is presented in Fig. 1.

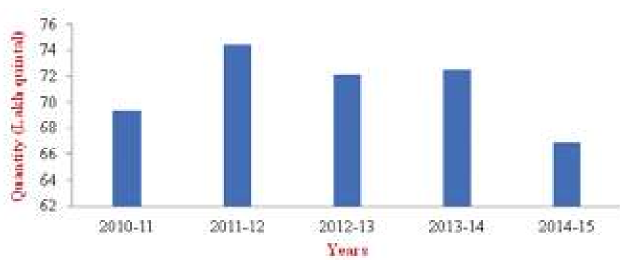

Fig. 1. Distribution of certified/ quality seeds of paddy (Anonymous 2016).

The Government of India periodically assesses the requirement and availability of seeds through State Governments and seed producing agencies in the bi-annual zonal seed review meetings and the national *kharif* and *rabi* meet. The DAC&FW facilitates the seed producing agencies to ensure the requirement of seeds to the maximum extent possible.

8. MOLECULAR RESEARCH IN SEED AND RELATED TRAITS

The important traits included under seed traits are seed dormancy, anaerobic germination, seed shattering, seed longevity, seed viability, seed weight and seed vigor. Phenotypic characterization on these traits has been reported for lot of genotypes. However, molecular studies on these traits are very scanty. Few QTLs and genes were identified for seed traits.

Seed dormancy is the failure in germination of mature and viable seeds under favourable condition. Generally the cultivated species are having no or short period of dormancy than the non-cultivated ones. The phenomena may be seen in either way i.e. weak dormancy promotes a uniform germination, whereas high dormancy prevents pre-harvest sprouting but inhibits germination and reduce seed quality. Thus, moderate dormancy levels (15-20 days) would be desirable. The dormancy lasts for few days to more than a month. This trait is controlled by both environmental as well as genetic factors inhabit in both maternal and embryonic tissues. Seed dormancy is genetically controlled by the genotypes of both the mother plant and the embryo. The maternal plant form tissues surrounding the embryo, such as the seed coat (testa) which creates barriers to radicle growth on imbibition. This "coat-imposed" dormancy depends on the anatomy of the seed. In rice, *qSD7–1*, a clustered QTL (*qSD7–1*/*qPC7*) was delimited to the pleiotropic Rc locus and found to control seed dormancy by regulating ABA biosynthetic pathway in rice. Moreover *Sdr4*, a global regulator of seed maturation was cloned in rice and was positively regulated by OsVP1 (Sugimoto et al 2010). The QTL mapped in the 12 chromosomes of rice except chromosome 10 included clusters QTL such as *qSD7*/*qPC7*, qSD1–2/qPH1 and qSD7–2/qPH7 (Ye et al. 2013).Further, soil flooding is one of the abiotic constraints in the rainfed lowland areas. Starchy seeds were shown to be especially tolerant of anaerobiosis because they are able to maintain a high energy metabolism under oxygen deficiency when compared with fatty seeds. The calcineurin-interacting protein kinase (CIPK15) gene was reported that signals pathway that regulates RAmy3D, which affects the expression of coleoptiles in anoxic conditions and anaerobic germination of rice. The first natural variant of QTL *qAG-9-2* that enhances anaerobic germination was reported and fine-mapped to *OsTPP7*, which is a gene encoding a trehalose-6-phosphate phosphatase (Kretzschmar et al. 2015). Two major QTLs for anaerobic germination viz., AG1 and AG2 were identified (Angaji et al. 2010). Researchers has also identified candidate proteins/genes for improving seed vigour in rice plants such as OsHSP18.2 (Kaur et al. 2015); OsALDH7, ACCase, PI3K (Liu et al. 2012); OsLOX (Wang et al. 2008). Only these few traits have been studied at molecular level and much closed gene were reported for seed related traits till date, which creates a huge gap in seed research.

9. PROCESS AND PROGRESS AT ICAR-NRRI ON SEED PRODUCTION AND RESEARCH

ICAR-NRRI is producing a large quantity of Breeder seed and Truthfully Labeled (TL) seed as per the indent of Department of Agriculture and Cooperation (DAC), Government of India, State Governments, other organizations and requirement of farmers. The institute is one of the volunteer centers for rice breeder seed production under ICAR. The AICRP-NSP (Crops) under ICAR-Indian Institute of Seed Science (IISS), Mau, Uttar Pradesh (the coordinating center) looks after the indent / allotment of seed production decided by DAC, Government of India and also facilitates monitoring of the seed production plots. The information from indent of the seed to the production and final lifting or sale is being documented in the form of BSP-I, BSP-II, BSP-III, BSP-IV and BSP-V. The BSP-I depicts the variety-wise requirement of Breeder Seed as per the Indent of Department of Agriculture Cooperation & Family Welfare compilation, BSP-II elaborates the variety-wise area of production and time of monitoring of Breeder Seed production plots, BSP-III includes State Monitoring Report for certification, BSP IV reports on quantity of Breeder Seed Produced (Actual Seed Production during *rabi* and *kharif* season) and BSP-V elucidates the lifting and non-lifting status of Breeder seed by indenter (center wise).

Breeder seed plots of the institute is monitored by a Central team constituted by ICAR-IISS, Mau to inspect the crop condition and field level purity; and also by a state level monitoring team for seed certification. The state level monitoring team includes breeder from NRRI, representatives of Odisha State Seed and Organic Product Certification Agency (OSSOPCA), State Agricultural University, Odisha State Seed Corporation (OSSC) and National Seed Corporation (NSC). The production of breeder seed is again reviewed by ICAR-DAC in the annual breeder seed review meeting.

Being a leading research institute of rice, ICAR-NRRI is supplying high quality breeder seeds to governments and other agencies to produce highest quality Foundation and Certified seeds for the country. During last 5 years the institute has produced about 3383.34 q breeder seed against the indent of 3333.50 q (Table 5).

Besides nucleus and breeder seeds, ICAR-NRRI has also been producing TL seed under Participatory Seed Production (PSP) programme where TL seed is produced in the farmer's field with inputs of the farmers and technical know-how and supervision of the NRRI scientists. This programme was initiated 5 years back and more than 3400 q seed of mega varieties viz. Swarna Sub-1, Pooja, Naveen and Sarala was produced.

The institute is also imparting training on quality seed production, management and storage, where farmers, state government officials, representative of various NGO's and seed producers were successfully trained during these last years.

Seed research was also a priority area along with seed production at our institute. The ICAR-NRRI has characterized the released varieties of the institute for days to

Table 5. Breeder seed indent and production of rice at NRRI during 2012-13 to 2016-17.

Year	DAC Indent	No. of varieties	Production (q)	Mega indented varieties
2012-13	571	25	651.35	Swarna Sub 1, Pooja, Shatabdi, Naveen, Sarala
2013-14	481	49	483.12	Swarna Sub1, Pooja, Naveen, Shatabdi, Sarala
2014-15	622	44	607.27	Swarna Sub 1, Pooja, Naveen, Shatabdi, CR 1014
2015-16	747	62	768.70	Swarna sub 1, Naveen, Varshadhan, CR Dhan 601, CR Dhan 501
2016-17	912.5	43	872.90	Swarna Sub 1, Naveen, CR Dhan 500, Shatabdi, Varshadhan,
Total	3333.5		3383.34	

seed dormancy and duration of viability which was depicted in NRRI Annual Report 2016-17. The seedling vigour of rice has direct relevance with antioxidant and amylose content in seed of pigmented rice. The pigmented rice are rich in genes for seed traits and are good source for identification of donor. The seed and seedling vigour are important traits especially for aerobic condition (Kumar et al. 2016). The molecular study for the seed traits has been initiated to find out the relevant markers to start breeding for seed traits and development of essentially derived varieties.

10. SEED MULTIPLICATION SYSTEM OF INDIA

Once a variety is released, it is the responsibility of the parent Institute to safe-guard the seed quality of that particular variety and to make available the indented quantity of Breeder seed of the variety in the seed chain. Maintenance breeding and production of Nucleus seed safe-guards the quality of the variety at Institute level and this Nucleus seed is used as basic seed for production of Breeder seed which cares for the quality of the National seed chain.

Indian seed system is a robust and full proof one that strictly adheres to three generation system (Breeder seed→Foundation seed→Certified seed); but in exigencies four or five generation model is followed where foundation seed stage II or certified seed stage II is produced.

The nucleus seed plots are planted in paired rows, each paired row contains plants from one single selected panicle. All around the plots 8 rows border line of the same variety (from bulk breeder seed) is transplanted. If any off-type plants are observed in any of the panicle progeny row, then that particular paired row is totally discarded/rogued-out. If any off-type plant with different grain type is marked (obviously observed after flowering) then the panicle progeny rows where the off-type is observed and the adjacent progeny rows (at both sides) are discarded to restrict chance pollination involving the off-type plant. After thorough roguing, sufficient true-to-type panicles (at least 500) are selected based on the morphological identity, uniformity and genetic purity to maintain nucleus seed for next generation.

The border row is supposed to restrict the foreign pollen flow and is not considered as seed. The panicle progeny rows are harvested and threshed separately; passes through table-top examination and later bulked as nucleus seed. This Nucleus seed is used for production of Breeder Seed.

Breeder seed (BS) is the progeny of nucleus seed, where, after every 6-8 rows of planting a skip row is allowed to facilitate intercultural operations and proper roguing. Here also 8 row borders all around the plot is maintained which is not considered as seed during harvest. Off-type plants if observed are simply rogued out. The crop is monitored by Central and State monitoring team. The genetic purity of breeder seed should be maintained at 100 percent. Breeder seed tag is golden yellow in colour and size is 12x6 cm.

Foundation seed is the progeny of breeder seed, called foundation seed stage I; and when foundation seed is the progeny of foundation seed, it is called foundation seed stage II. The foundation seed stage I is used for the production of foundation seed stage II. The minimum seed standard for Foundation seed stage I and stage II are same. Production of Foundation seed stage II is undertaken only when it is expressed by the seed certifying agencies that breeder seed is in short supply and stage II foundation seed has to be produced to meet the seed demand. Foundation seed is monitored by the state certifying agency. The genetic purity of foundation seed should be maintained at 99.5 percent. Foundation seed tag is white in colour and size is 15x7.5 cm.

Certified seed is the progeny of foundation seed I or II. But, certified seed can also be the progeny of certified seed provided this reproduction does not exceed three generations beyond foundation seed stage I. Certified seed produced from foundation seed is called certified seed stage I, while Certified seed produced from certified seed is called certified seed stage II. Certified seed is monitored by the state certifying agency and its genetic purity is 99%. Certified seed tag is blue in colour and size is15x7.5cm.

One additional class of seed is produced and marketed in India, known as Truthfully labeled seed (TL Seed) where certification is not required but, minimum seed standard must be fulfilled. It is applicable to both notified varieties and variety developed by any person or agency. Seed inspectors are the persons who can guard the quality of seed which is on sale. So the quality of marketed TL seed can be inspected by them if doubt on quality arises; and if it fails the quality test, the sale of that seed can be stopped. The tag colour of TL seed is opel green and size is 15x10 cm.

11. KNOWLEDGE GAPS

- Non-availability of many high yielding varieties in seed chain: A large number of high yielding varieties (HYVs) suitable for different agro-climatic situations are released in India. But, many high yielding varieties are not under seed chain may be due to lack of popularization. Therefore, it is required to include these HYVs under front line demonstration (FLD) programmes for popularization among the farmers; and information regarding these varieties need to be communicated to all the officials working under seed production and marketing for there further popularization.

- Insufficient quantity of quality seed: Available quality seed of improved rice varieties and hybrids is many times inadequate due to climatic disturbance, improper technology, wrong handling etc. and is considered as one of the major constraints for higher productivity. This problem may be due to the fact that (i) presently, high volume-low quality seeds are available with the farmers and low volume-high quality seeds are mostly available with the public sector, (ii) non-lifting of produced breeder seed by Government Institutions and private agencies, which hamper the production of sufficient quantity foundation and certified seed. These problems can be sorted out by (a) engagement of more officials for monitoring of quality seed production, (b) involvement of more volunteer agencies such as village-based/community based seed banks to take up the Foundation and Certified seed production programme and (c) designing a policy framework for advance payment of indented quantity of seeds to limit the problem of non-lifting.

- Seed quality deterioration: Seed is a biologically living entity, whose quality deteriorates if the minimum standard for seed production and storage steps are not followed. Varietal deterioration occurs due to repeated multiplication of the same varieties year after year probably due to undesirable pollination or out-crossing, occasional mutation and genetic drift. The formal seed system guards against the deterioration of seed quality through production of Nucleus, Breeder, Foundation and Certified seed, the quality of which is well monitored. But due to non-availability of this quality seed, large number of farmers depend on their farm-saved seeds or TL seeds from the market where quality parameters are not well-guarded. So these seeds used by the farmers show presence of seed of other varieties, mixtures, impurities and less germination percentage that affects the total grain production. This seed quality deterioration can be checked through; (i) Awareness generation among seed growers and farmers regarding quality seed and (ii) Imparting training on Quality Seed production technology to the seed growers and farmers.

- Long time span for seed quality testing: Grow-out-test (GOT) is a procedure to test the genetic purity of the seed. It involves assessing the several morphological characteristics in different developmental stages which takes a long time span, almost the entire cropping season. Furthermore, GOT is a simple way to analyze the genetic purity based on the basis of visual detection which can be easily affected by growing conditions. To make it more exact and to reduce the time span, DNA based testing will be a proven alternative for GOT.

- Non assurance of genetic purity of MAS developed varieties: The present era of molecular breeding has now accelerating gene introgression in existing varieties resulting in release of varieties like Improved Tapaswini, Improved Lalat, Swarna-Sub1 etc., which are now under seed chain. Most of these MAS developed varieties are quite similar with parents except the introgressed genes. Here, selection of true to type plants of varieties developed through MAS (where no distinct phenotypical difference) can only be possible through molecular level detection or though DNA fingerprinting. This molecular marker based genetic purity testing (MGPT) at nucleus seed level will provide 100% purity and high level of seed purity on subsequent class of seed.

- Awareness and training: Intermediaries seed producers involved in production and distribution of seeds have a large contribution in supply of paddy seeds to the farmers. The question arises whether all these seeds are quality seeds? The report says, unawareness in many producers regarding quality seed production procedure leads to poor quality control. Intensive training to trainers and seed producers about seed production, quality management and purity testing will help in increasing the high volume quality seed.
- Seed technology research: Characterization of released varieties for seed traits like seed viability duration or longevity and seed dormancy is poorly documented. These information are always needed by the producers and farmers for better seed multiplication, proper time of harvesting and safe storage. There are various theories reported for genetic basis and physiological basis of seed related traits. But, utilization of these information is very poor. A strong platform for seed research can be a base to utilize the existing information and dissecting the molecular, proteomics and metabolomics basis on expression of seed related traits. The advancement of new molecular technology will explore different seed traits which will lead to seed trait specific breeding to improve the cultivar performance such as improvement of cultivar for capacity to germinate under anaerobic condition, no seed shattering, prolonged seed longevity, intermediate seed dormancy, high seed viability, appropriate seed dimension, higher seed weight, seed pigmentation if necessary, improve seed coat permeability etc. Introgressions of these traits are mostly relevant for high seed vigor, seed storage and optimum plant stand in field.

12. WAY FORWARD

Indian seed delivery system for farmers has a good structural network for sufficient availability of seed. But, the SRR and VRR are still under desirable limit. Many points have been discussed in this chapter related to production, management and research options for safe guarding the seed quality and to speed up the process of deliveries. QTLs have been identified but for seed traits, only few candidate and functional genes are known till date. The emphasis and initiatives now need to be made for (i) designing policy framework for timely lifting of seed, (ii) involvement of more officials for proper monitoring to produce quality seed, (iii) authorization to national level institute for issuing certification for seed production plot; this will be helpful to cover more seed plot area for certification, (iv) mapping and development of marker for introgression of seed traits, (v) involvement of molecular tools for rapid purity testing procedure,(vi) advanced level capacity building of stake holders involved in seed chain, (vii)creation of buffer stock of seed in form of seed bank at village level, and establishing seed hubs,(viii)development of a local seed system as an alternative to formal system (like 4S4R model developed by ICAR-NRRI, Cuttack).Once these points are taken care of, the quality seed production and distribution system will smoothen and the Country will achieve higher rice grain production.

References

FAO (2017) Food and Agriculture Organization of the United Nations, Rome, Italy, 20(1), April 2017.

Annual Report (2016-17) Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers welfare, Government of India, Krishi Bhawan, New Delhi.

Hasanuzzaman M (2015) Concept note. http://hasanuzzaman.weebly.com/uploads/9/3/4/0/934025/seed quality.

Chauhan JS, Prasad Rajendra S, Pal Satinder and Choudhury PR (2017) Seed systems and Supply chain of rice in India. Journal of Rice Research 10(1): 9-16.

Reddy Ch Ravinder, Tonapi VA, Bezkorowajnyj PG, Navi SS and Seetharama N (2007) Seed system innovations in the semi-arid tropics of Andhra Pradesh, International Livestock Research Institute (ILRI), ICRISAT, Patancheru, Andhra Pradesh, India, 224.

Anonymous2016. Agricultural Statistics at a Glance (2015) Directorate of Economics & Statistics. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi, 479.

Sugimoto Kazuhiko, Yoshinobu Takeuchi, Kaworu Ebana, Akio Miyao, Hirohiko Hirochika, Naho Hara, Kanako Ishiyama, Masatomo Kobayashi, Yoshinori Ban, Tsukaho Hattori, Masahiro Yano (2010) Molecular cloning of *Sdr4*, a regulator involved in seed dormancy and domestication of rice. Proceedings of the National Academy of Sciences USA107 (13): 5792–5797.

Ye H, Beighley DH, Feng J, Gu XY (2013)Genetic and physiological characterization of two clusters of quantitative trait loci associated with seed dormancy and plant height in rice. G3 (Bethesda) 3:323–31.

Kretzschmar T, Pelayo MAF, Trijatmiko KR, Gabunada LFM, Alam R, Jimenez R, Mendioro MS, Slamet-Loedin IH, Sreenivasulu N, Bailey-Serres J, Ismail AM, Mackill DJ, Septiningsih EM (2015) A trehalose-6-phosphate phosphatase enhances anaerobic germination tolerance in rice. Nature Plants: 15124.

Angaji SA, Septiningsih EM, Mackill DJ and Ismail AM (2010) QTLs associated with tolerance of anaerobic conditions during germination in rice (Oryza sativa L.). Euphytica 172:159 - 168.

Kaur H, Petla BP, Kamble NU, Singh A, Rao V, Salvi P, et al. (2015) Differentially expressed seed aging responsive heat shock protein OsHSP18.2 implicates in seed vigor, longevity and improves germination and seedling establishment under abiotic stress. Frontiers in Plant Science 6:71.

Kumar R, Kumawat N, Kumar S, Kumar R, Kumar M, Sah RP, Kumar U and A Kumar (2016) Direct Seeded Rice: Research Strategies and Opportunities for Water and Weed Management. Oryza 53(4): 354-365.

Liu J, Zhou J, and Xing D (2012) Phosphatidylinositol 3-kinase plays a vital role in regulation of rice seed vigor via altering NADPH oxidase activity. PLoS ONE 7:e33817.

Wang R, Shen WB, Liu L, Jiang L, Zhai H and Wan J (2008) Prokaryotic expression, purification and characterization of a novel rice seed lipoxygenase gene OsLOX1. Rice Science 15:88–94.❄